THE WEATHER AND CIRCULATION OF MARCH 1956 [1]

A Month with a Marked Progression of Weekly Temperature and Circulation Anomalies

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1. THE POLAR VORTEX

The dominant feature of the mean circulation for the month of March 1956 was a vigorous cyclonic vortex which became established over the polar basin early in the month, persisted throughout the period, and produced the largest 700-mb. height anomaly (−520 ft.) observed on the mean chart (fig. 1). During the decade for which data have been available in the polar region, a departure from normal of this magnitude has been observed only once before. On this occasion, February 1954, the anomaly for the month averaged −550 ft. It is of considerable interest that most other components of the circulation patterns of these two months were also remarkably similar, as becomes evident if the 30-day mean chart for this March (fig. 1) is compared with its counterpart for February 1954 (fig. 1 of [1]).

2. THE ZONAL INDEX AND JET STREAM

The long and record-breaking persistence (since November 1955) of subnormal zonal index values has been a highlighted topic in several previous articles of this series [2, 3, 4]. However, this trend was finally reversed toward the end of February [5], and the zonal index at 700 mb. for the period February 29–March 4 exceeded the normal by 4.8 m. p. s. Thereafter, strong zonal westerlies governed the circulation during March, averaging 12.1 m. p. s. (3 m. p. s. above normal) for the month.

The axis of the 700-mb. jet stream associated with this flow was near its normal latitude of 45° N., with a sharp profile and strong shear both to the north and south (fig. 2). Figure 3A shows that this narrow belt of fast westerlies circled virtually the whole of the Western Hemisphere, with wind speeds strongest relative to normal (fig. 3B) in the western Atlantic (+8 m. p. s.) and also over a broad zonal expanse of the Pacific (+6 m. p. s). Branching of the jet stream occurred, however, in the central Atlantic as blocking assumed control over Europe. A secondary jet, south of the polar vortex, averaged 7 m. p. s. at about 77° N., about three times the normal wind speed at that latitude (fig. 2).

The flow pattern at 200 mb. (fig. 4) resembled that at the 700-mb. level quite closely, except that a branch of the jet stream separated from the main axis in the western Pacific to dip southeastward toward the Hawaiian Islands and then return northeastward to rejoin the principal current over the United States.

3. THE CIRCULATION REVERSAL

The circulation at the 700-mb. level at middle latitudes for the month of March underwent a fundamental change in planetary wave pattern about midmonth. Consequently the two halves of the month tended to offset each other, resulting in relatively small residual anomalies for the month as a whole over the United States in both 700-mb. height (fig. 1) and surface temperature (Chart I-B). The first half-month (fig. 5A) was roughly a continuation of the high-index pattern which characterized the latter portion of February [5]. The flow was relatively flat and sufficiently fast to support very long planetary waves. In fact, the hemispheric wave number was reduced to 3 at middle latitudes. Of particularly large longitudinal dimension was the wavelength from the Japanese to the United States trough. Note that strong positive tilt from NE to SW typical of high-index flow was characteristic of both these troughs. One remarkable feature of the circulation of this period is the fact that only one closed vortex of any magnitude existed, and that was the polar vortex previously mentioned. It became very intense during this period with a departure from normal of −640 ft. and was instrumental in introducing extremely cold air into Alaska and Canada, as will be considered later. (See sec. 7.)

On the other hand, figure 5B reveals a quite different regime for the second half-month. The zonal index dropped to 10.4 m. p. s., resulting in shorter wavelengths and an increase in hemispheric wave number. This wavelength adjustment was accomplished by the appearance of a trough over the eastern Pacific in almost the same longitude as the ridge in the previous half-month. A similar rearrangement occurred downstream as the ridge progressed well inland over the Rockies, and a full latitude trough developed off the east coast. One additional marked change occurred farther downstream in the eastern Atlantic and Europe. The Eurasian trough, which was so prominent early in the month, proved short-lived,

[1] See Charts I–XV following p. 126 for analyzed climatological data for the month.

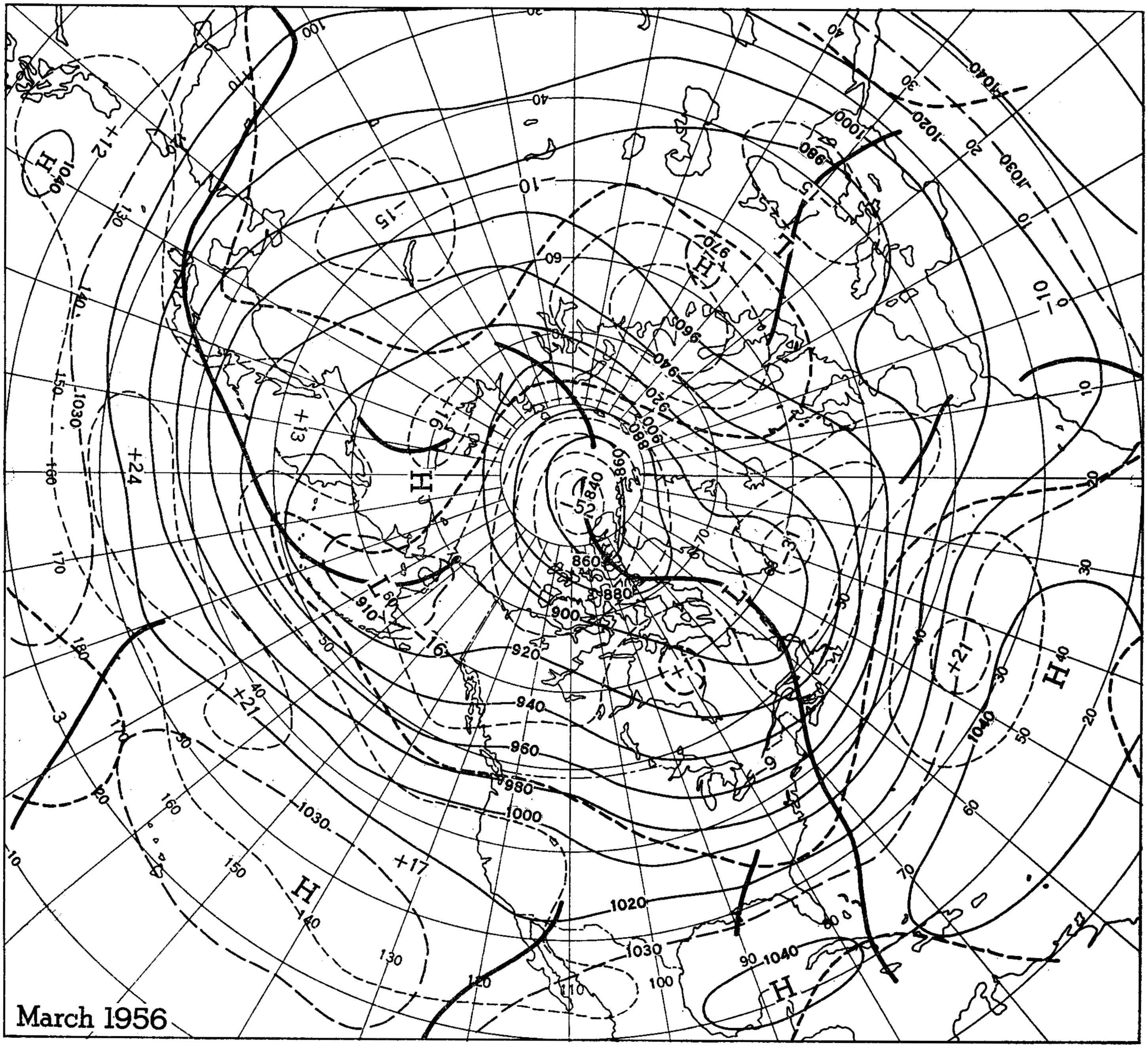

FIGURE 1.—Mean 700-mb. height contours and departures from normal (both in tens of feet) for March 1956. The polar region was the site of the largest anomaly center (−520 ft.) This vortex was the only closed low center of any consequence observed on the mean chart. Elsewhere in the Western Hemisphere anomalies were relatively small, particularly over the United States.

and the pattern of the latter half-month returned to the pronounced blocking regime which strongly dominated Europe during February [5]. The seat of blocking lay over Finland, where an anomaly center of +580 ft. was observed. Several blocking surges proceeded westward from this center during the month. This is attested by the belt of sizeable positive anomaly which extended westward across Greenland and most of Canada. It was one such blocking surge which set the stage for heavy snows in the Northeast. (See sec. 6.)

4. EASTWARD MOTION OF 5-DAY MEAN FEATURES

The circulation reversal described above was the consequence of a fairly regular eastward motion of most 5-day mean circulation components. This progression occurred over the relatively long span of 6 weeks, as illustrated by the series of charts in figure 6. The average 5-day mean trough speed of 6° longitude per week at 45° N. for the winter season over North America [6, 7] was roughly doubled during this period. These considerations sug-

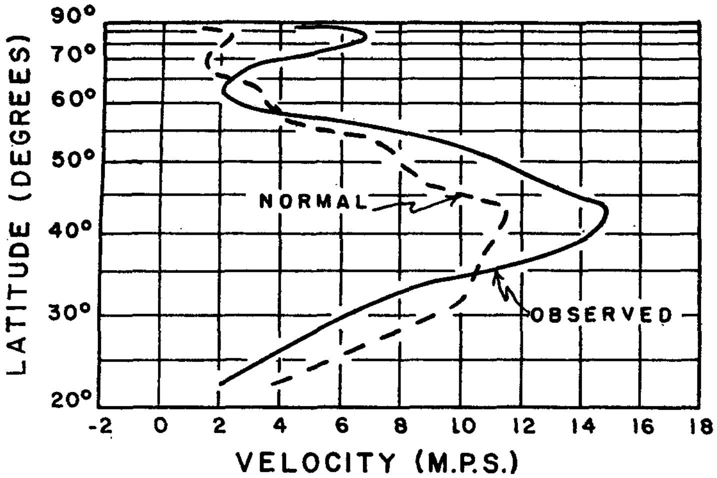

FIGURE 2.—Mean 700-mb. zonal wind speed profile for the Western Hemisphere for March 1956, with the normal profile dashed. The mid-latitude jet stream was near its normal latitude, but with speeds higher and profile sharper than normal. Note also that the polar jet was well established.

gested that, while troughs usually move eastward on 5-day mean charts, such motion may be most characteristic of periods when fast zonal westerlies and a strong polar vortex occur simultaneously.

This progression is perhaps best illustrated by following the progress of the trough located near the Pacific coast early in March (fig. 6A). During the next week, as rapid filling took place in the Gulf of Alaska, it redeveloped over the central United States, extending from the Great Lakes southwestward (fig. 6B). After this initial jump across the mountains, it moved eastward in regular steps, and by the next week (fig. 6C) had progressed almost to the Appalachians. By this time, a following ridge had moved to a position along the west coast (fig. 6C) after having made a rapid transit of the Pacific. It was this pronounced ridge-trough system which determined the character of the flow pattern for the first half-month (fig. 5A).

Thereafter, this pattern continued on an eastward course until the ridge was well established over the Rockies and the trough well off the east coast (fig. 6D). This was the dominant pattern previously described for the second half of the month (fig. 5B). It should be noted that another trough had appeared in the Gulf of Alaska during this period (fig. 6D) after having similarly made rapid progress across the Pacific.

By month's end (fig. 6E) the pattern became complicated by the advent of blocking over the North Atlantic and Canada which shortened the wavelength and rendered the continuity less straightforward. Nonetheless, progressive motion can still be ascribed to the Pacific trough, which moved inland, and to the Atlantic coastal trough, which moved slightly farther east. Meanwhile, a new trough developed to the lee of the Rocky Mountains, thus creating a short wavelength.

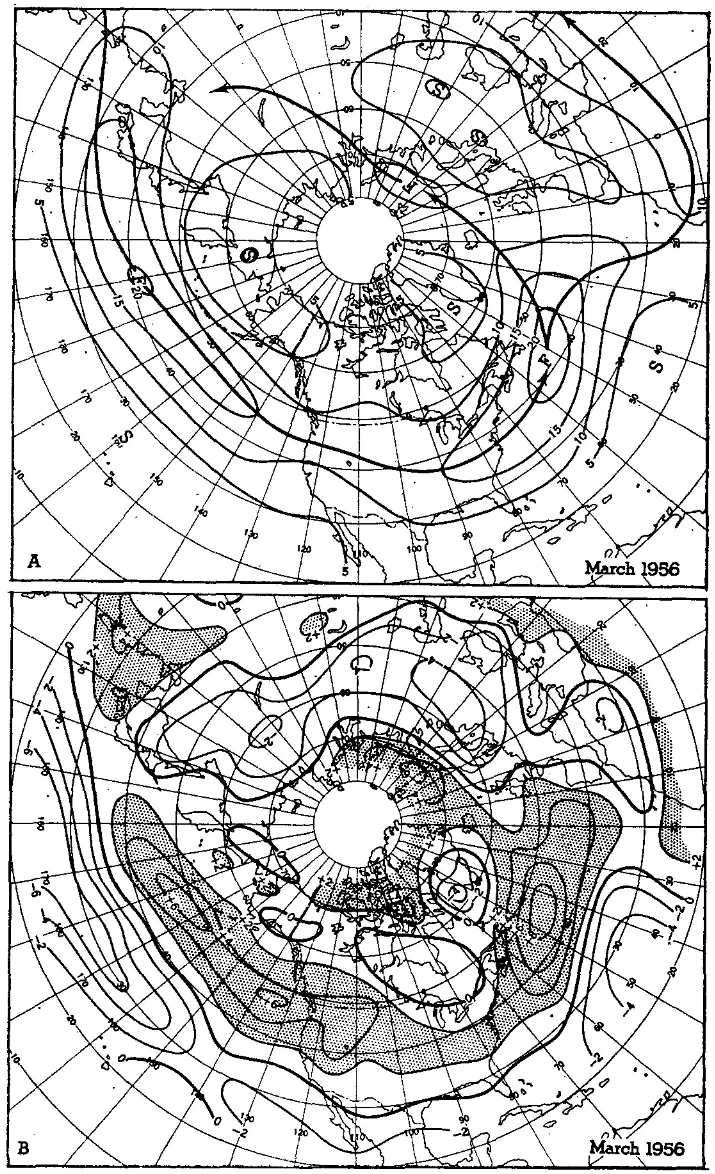

FIGURE 3.—(A) Mean 700-mb. isotachs, and (B) departure from normal wind speed (both in meters per second) for March 1956. Solid arrows indicate position of mean 700-mb. jet stream, which was stronger than normal and well organized in a single narrow band from Japan to the Central Atlantic. Here it split into two branches, one to the north and the other to the south of blocking over Europe.

The chart for the first week in April (fig. 6F) has been included, since by this time a full cycle had been completed over the United States, as this pattern closely resembles that for the corresponding period in March (fig. 6B). Also, eastward motion is still discernible, though it is mainly limited to lower latitudes because of the blocking over Canada. A sequence somewhat similar to this has been described by Namias using a series of monthly mean charts [7].

5. THE TEMPERATURE REGIME

As the series of planetary waves described in the preceding section traversed the United States, radically differing

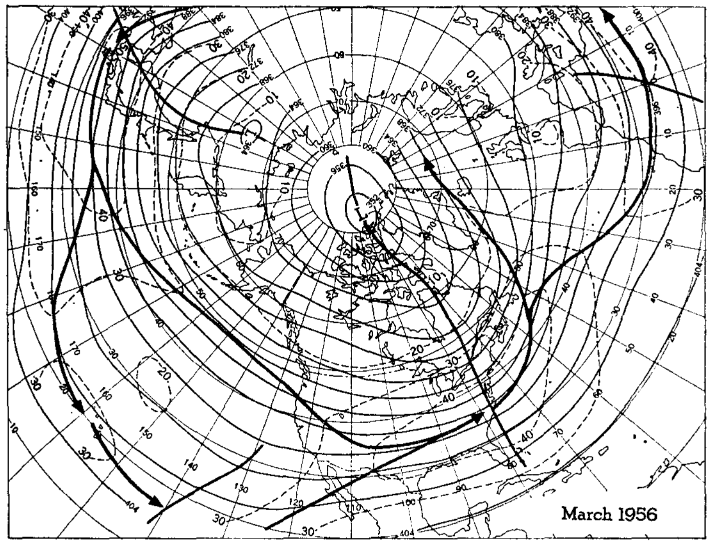

FIGURE 4.—Mean 200-mb. contours (solid lines labeled in hundreds of feet) and isotachs (dashed lines, in meters per second) for March 1956. The westerlies were fast and flat with a very long wavelength between minimum-latitude troughs. The jet-stream pattern was similar to that at 700 mb., except that a tropical branch left the principal current in the western Pacific to dip southward over the Hawaiian Islands before returning to the main jet over the United States.

temperature regimes developed. These contrasts are highlighted by the odd circumstance that such widely separated stations as Sheridan, Wyo., Amarillo, Tex., and Schenectady, N. Y., each recorded both new high and new low temperatures for the month.

The half-month oscillation previously noted from the flow patterns of figure 6 was even better delineated in the weekly temperature distributions (fig. 7). Initially (fig. 7A), warm conditions prevailed over most of the country, although cooler air had begun to enter the west. This cold surge, following rapidly in the wake of the mean trough which traversed the country (fig. 6B and C), overspread first the western half (fig. 7B) and then almost the whole of the Nation (fig. 7C). It is noteworthy that the pattern in figure 7C is almost the exact reverse of that of figure 7A.

TABLE 1.—*Record-breaking temperatures during the first half of March 1956*

Station	Temperature (° F.)	Date
A—Minima		
Yuma, Ariz.	33	13
Santa Maria, Calif.	29	5
Amarillo, Tex.	9	12
Missoula, Mont.	−5	11
Sheridan, Wyo.	−18	11
B—Maxima		
Wichita Falls, Tex.	92	5
Norfolk, Va.	83	7
Topeka, Kans.	83	5
Cincinnati, Ohio	75	5
Schenectady, N. Y.	50	2

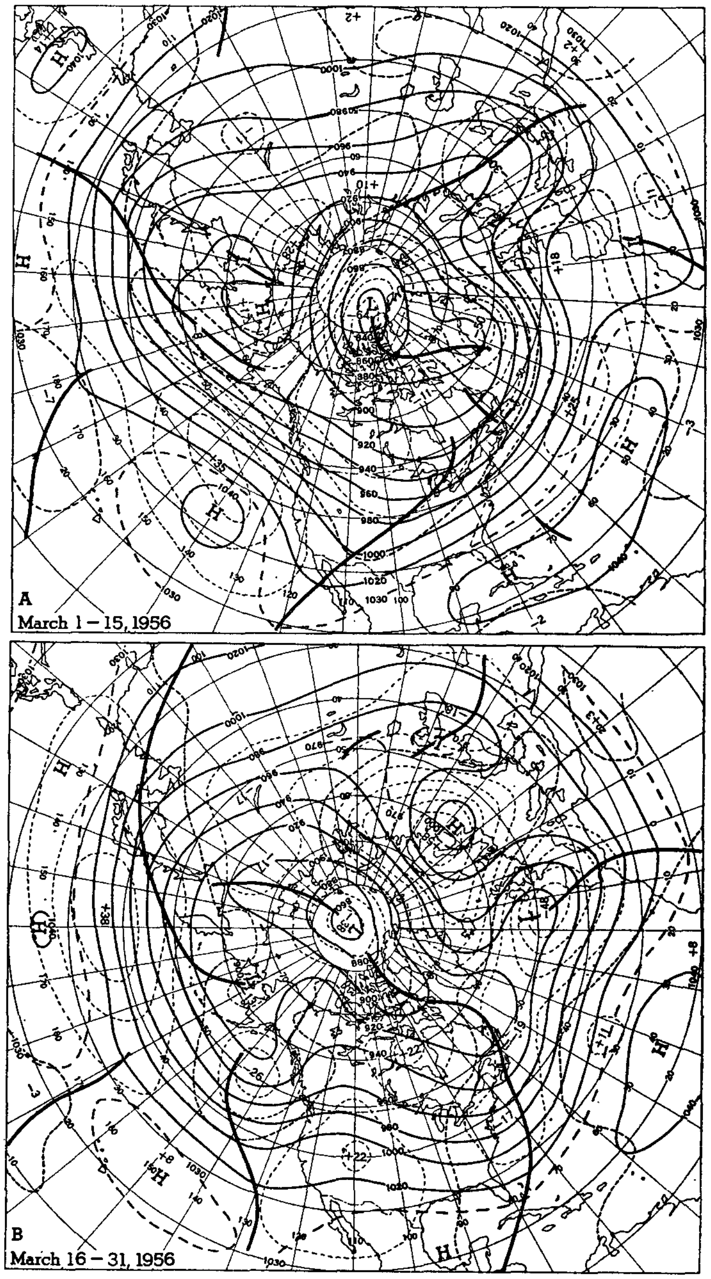

FIGURE 5.—700-mb. height contours and departures from normal (in tens of feet) (A) March 1–15, 1956, and (B) March 16–31, 1956. The circulation for the first half-month manifested the features typical of high index: westerlies of high speed and small amplitude with very long wavelength. The zonal index diminished in the second part of the month, requiring an increase in hemispheric wave number. The adjustment in circulation pattern incident to this change markedly altered the flow pattern over North America.

During this sequence, as the intense cold outbreak replaced the warm regime, several new records were established for temperature minima in the West and maxima in the East. A few are listed in table 1.

Thereafter the mean ridge moved inland over the Rockies (fig. 6D), flooding the West with a broad and unusually warm current to its rear (fig. 7D). This warm

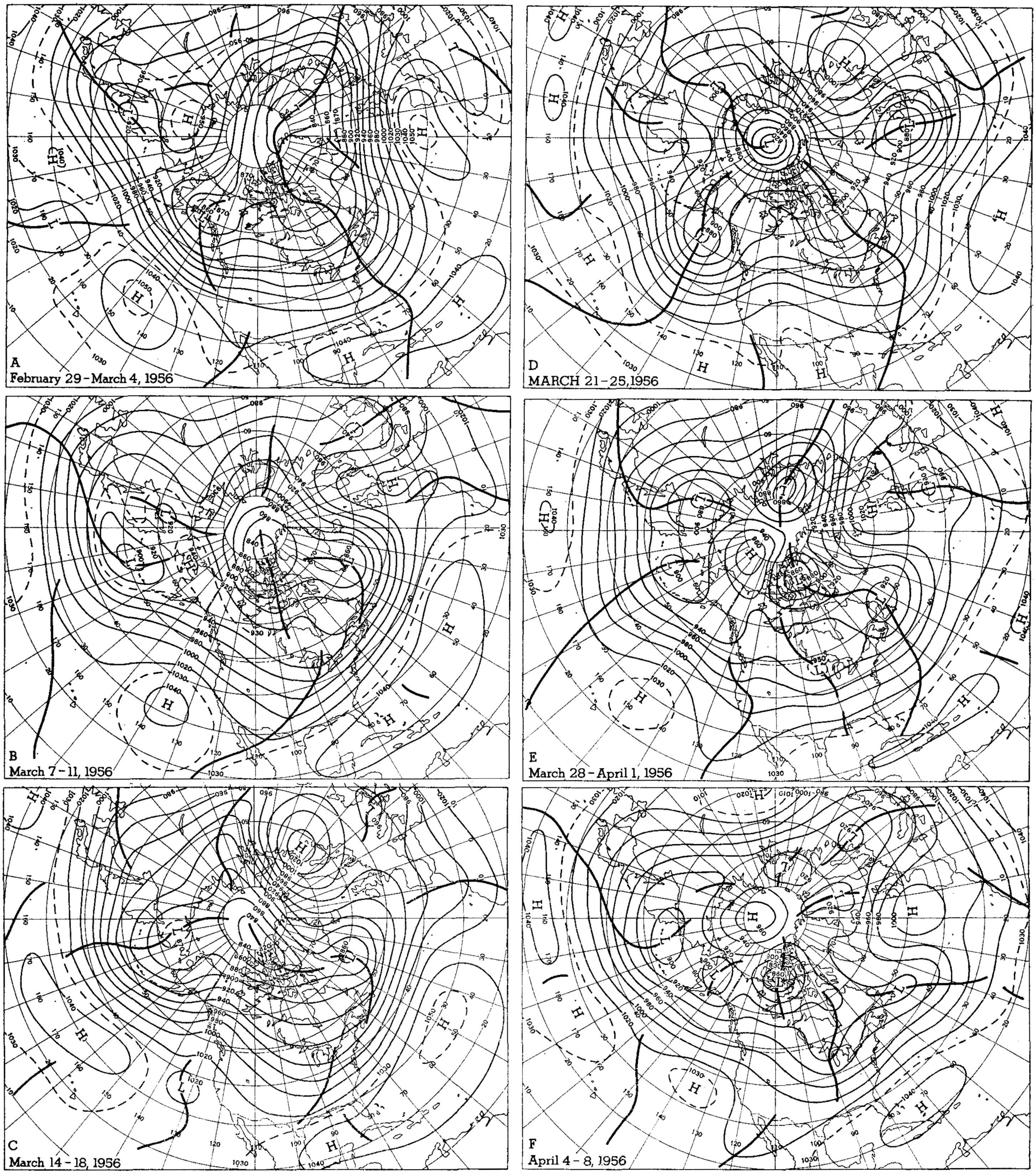

FIGURE 6.—5-day mean 700-mb. height contours in tens of feet for (A) February 24–March 4, (B) March 7–11, (C) March 14–18, (D) March 21–25, (E) March 28–April 1, and (F) April 4–8, 1956. As a consequence of fast westerly flow at middle latitudes in combination with the polar vortex, most features of 5-day mean charts progressed steadily eastward. This brought about a remarkable oscillation with reversal in pattern every second week.

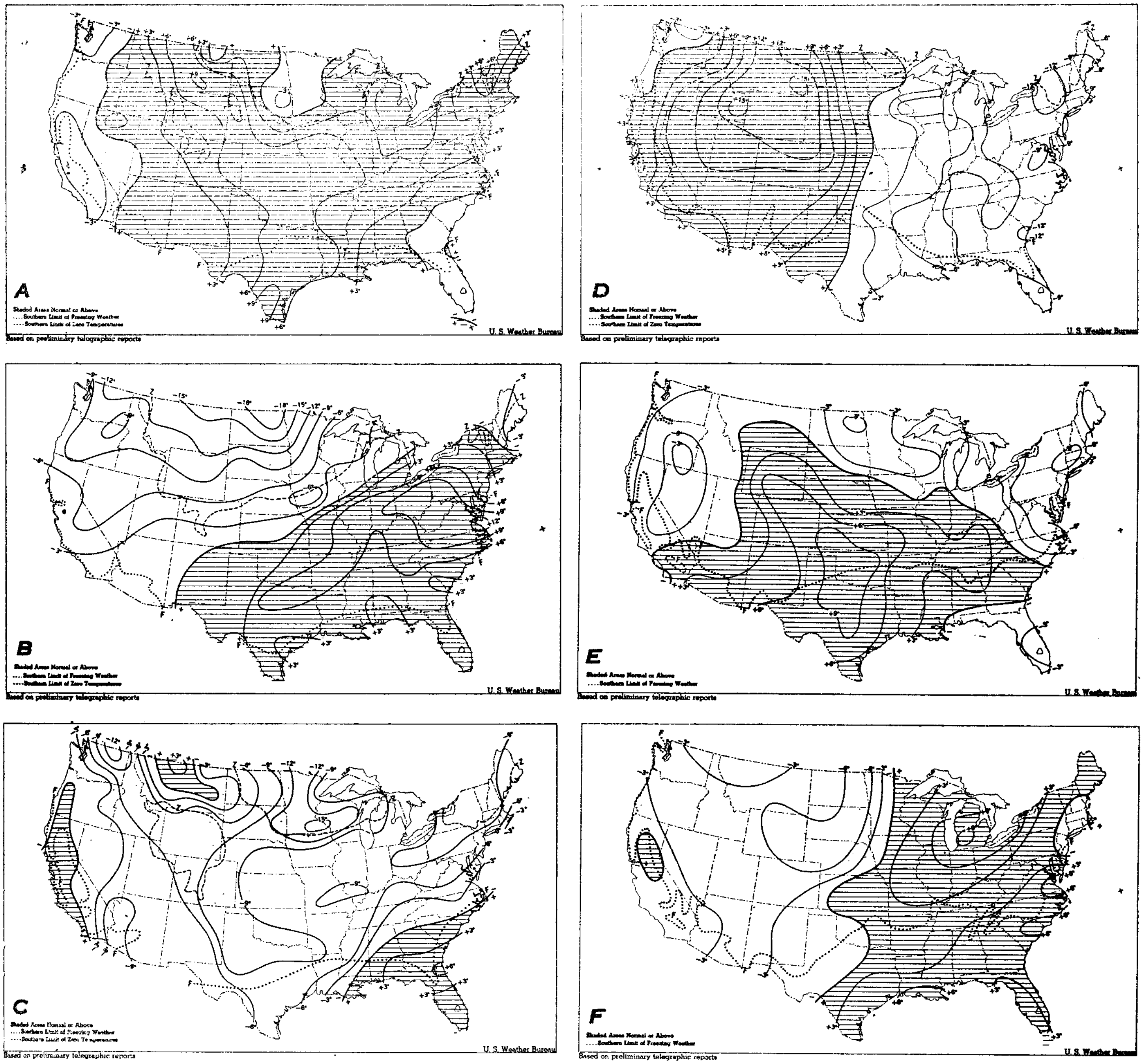

FIGURE 7.—Departure of average temperature from normal for the weeks ending at midnight local time (A) March 4, (B) March 11, (C) March 18, (D) March 25, (E) April 1, and (F) April 8, 1956. The cold air which had just entered the Pacific States the first week of the month marched steadily eastward until it overlay most of the country by the week ending March 19. By that time, however, above normal temperatures had begun to appear in Montana and along the west coast. This mild surge in turn moved east to overspread the western half of the country the following week (ending March 25). This then moved eastward and was replaced in the West once more by a new outbreak of cold air. (From *Weekly Weather and Crop Bulletin, National Summary*, vol. XLIII, Nos. 10 through 15, March 5 through April 9, 1956.)

air in turn continued eastward, until by month's end mild weather occupied a wide area embracing most of the central and southern States (fig. 7E). By this time a full cycle had been completed since this pattern was very similar to that at the beginning of the month (fig. 7A). Again new temperature records were established, but this time in an opposite sense. To permit comparison, a few instances have been listed in table 2.

The oscillation described above was not confined to March, but continued into the first part of April. The warm weather advanced to the eastern half of the country, and cold air reoccupied the West (fig. 7F). Once again a

TABLE 2.—*Record-breaking temperatures during the second half of March 1956*

Station	Temperature (° F.)	Date
A—Maxima		
Dallas, Tex.	95	27
Amarillo, Tex.	86	26
Phoenix, Ariz.	91	24
Winnemucca, Nev.	75	24
Sheridan, Wyo.	72	26
B—Minima		
Miami, Fla.	56	21
Providence, R. I.	13	25
Scranton, Pa.	11	21
Schenectady, N. Y.	10	21 and 25
Rochester, Minn.	−12	15

close resemblance can be observed between figure 7F and its counterpart of the corresponding week in March (fig. 7B).

6. PRECIPITATION

The precipitation pattern was similarly largely controlled by the 5-day mean trough described in section 5 which entered the country early in the month and thereafter moved eastward to the Atlantic. Once it came into position to draw moist Gulf air into its circulation, it produced copious precipitation. Except for Florida, therefore, the eastern third of the country received ample rainfall (Chart III). A particularly intense storm which formed over the Southwest and subsequently moved through the Ohio Valley caused flooding in the Allegheny River and its tributaries on the 7th and 8th of the month.

Relatively heavy precipitation was also observed in the northern tier of States, mainly as snow. Several storms (Chart X) which moved into, or developed in, the Plains States proceeded along a storm track roughly east-northeastward through the Ohio Valley and produced snow and sleet throughout the Northern States from the northern Great Plains eastward. In some instances, these storms reached blizzard proportions. Record snow accumulations were reported in many areas particularly in the Northeast (Chart V). All snowfall records were broken at Devils Lake, N. Dak., with a fall of 13.4 inches in 24 hours on the 27th and 28th and a total accumulation for the month of 25.6 inches. Numerous stations throughout the mountain regions of the Northeast reported the snowiest March on record, and New York City, with a total fall of 20.6 inches, suffered its heaviest snowfall since 1919. The snowstorm of March 16–17 has been briefly described by Sable [8] and Pack [9], but the most crippling storm occurred March 18–19 when a total of 13.5 inches of snow descended on New York City. A detailed treatment of the latter storm by Mook and Norquest begins on p. 116 of this issue.

In an attempt to isolate the meteorological factors contributing to snow at New York City, a composite chart was prepared comprising 10 5-day mean 700-mb. charts when snowfalls exceeding 5 inches occurred. This chart,

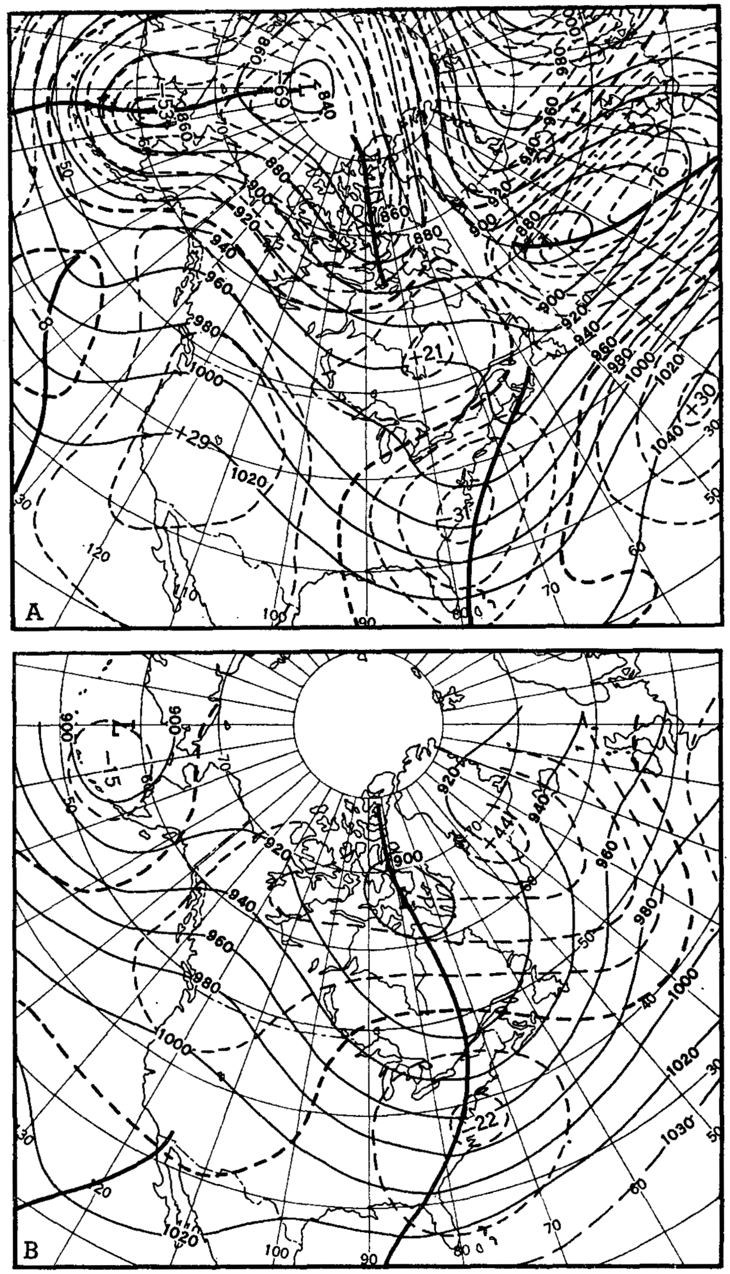

FIGURE 8.—(A) Mean 700-mb. height contours and departures from normal in tens of feet for the 5-day period March 17–21, 1956, during which time New York City sustained a heavy snowfall. (B) Composite mean 700-mb. height contours and departures from normal (tens of feet) for 10 5-day periods from 1947 to the present when snowfalls with accumulations greater than 5 inches occurred at New York City.

shown in figure 8B, closely resembles a composite chart prepared by Klein [10] for all daily 700-mb. maps with 1 inch or more of snowfall at Washington, D. C., since 1945. It illustrates the features listed by him and Namias [10] as being essential to snowstorm development in the Northeast: (1) The advection of cold air, (2) maintenance of cold air, (3) a mechanism for supply of warm moist air.

The first requirement is met (fig. 8B) by the existence of a large ridge in northwestern Canada to provide the gradient for the transport of cold air into the United States.

The second feature is provided by blocking to the north, as evidenced by the center of positive anomaly over Greenland (fig. 8B) and the tongue of above-normal heights extending across northern Canada. The block also serves to slow the eastward progress of the storm center and permit longer duration of the snowstorm.

Adequate moisture supply, the third requirement, is usually insured by confluence between cold air from Canada and warm moist air from the Gulf. The confluent pattern also provides a sharp frontal contrast necessary for rapid lifting of the tropical air.

This composite chart is to be compared with the 5-day mean chart (fig. 8A) which covers the period of heavy snow at New York City. It is evident that the first two conditions were met since (1) the ridge over the Canadian Rockies was well developed, and (2) a blocking surge was centered over James Bay with a positive anomaly of +210 ft. However, the third condition, a confluence pattern, did not obtain in this instance, and inspection of daily charts suggests that the Atlantic Ocean rather than the Gulf of Mexico was the principal moisture source. This is also suggested by the presence of a negative 700-mb. height anomaly center near Cape Hatteras with easterly anomalous flow components in the Northeast in both figures 8A and B.

In sharp contrast to the East, a large fraction of the Southwest, together with the Central and Southern Plains States, experienced drought conditions, and many areas received no rain at all (Chart II). Such widely separated points as Los Angeles, Calif., Springfield, Mo., Albuquerque, N. Mex., and Dallas, Tex., all experienced their driest recorded March. This accumulated moisture deficiency was one of several months' duration, during which this area has experienced ¼ to ½ the normal precipitation.

The combination of dry topsoil and high winds produced some of the most severe duststorms of recent years in the western Great Plains. One such storm developed on March 21 as a squall line moved through Texas and triggered several tornadoes along the Coastal Bend and in central areas. A particularly bad duststorm entered this area again on March 27–28.

7. ALASKAN COLD

There remains one additional consequence of the polar vortex to discuss. The anomalous northerly flow to the west of this center was rather strong and poured repeated surges of air from the Arctic icecap into Alaska and northwestern Canada. This was particularly true of the first half of the month, when all of Alaska suffered cold of unusual severity. Numerous alltime records for March minima were established and a few have been listed in table 3.

Unseasonably cold weather has persisted in Alaska for a remarkably long period. February 1956 was reported in last month's article of this series [5] as also being unusually cold, and this has been characteristic of the past fall and winter season as well. In fact, some areas have been cold for even longer periods. Monthly mean temperatures at Annette, for example, have continued subnormal for 14 consecutive months, and at Bethel and McGrath for 12.

TABLE 3.—*Record minimum temperatures at Alaskan stations during March 1956*

Station	Temperature (° F.)	Date
Northway	−56	2
McGrath	−51	2
Fairbanks	−49	1
Cordova	−24	3
Anchorage	−22	5 and 9
Yakutat	−13	3

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8. E. Sable, "Northeastern Snowstorm, March 16–19, 1956," *Weekly Weather and Crop Bulletin, National Summary*, vol. XLIII, No. 12, March 19, 1956, p. 1.
9. A. B. Pack, "Northeastern Snowstorm, March 16–19, 1956," *Weekly Weather and Crop Bulletin, National Summary*, vol. XLIII, No. 12, March 19, 1956, p. 1.
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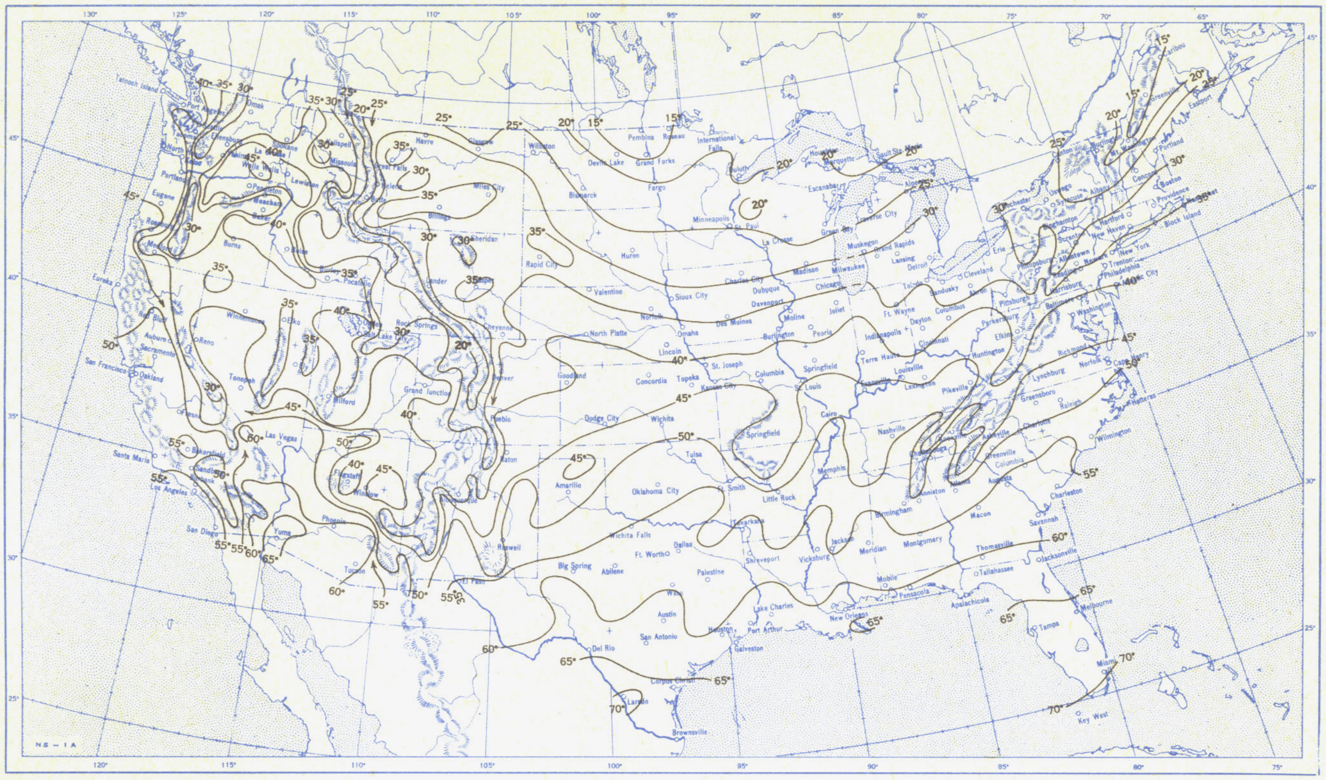
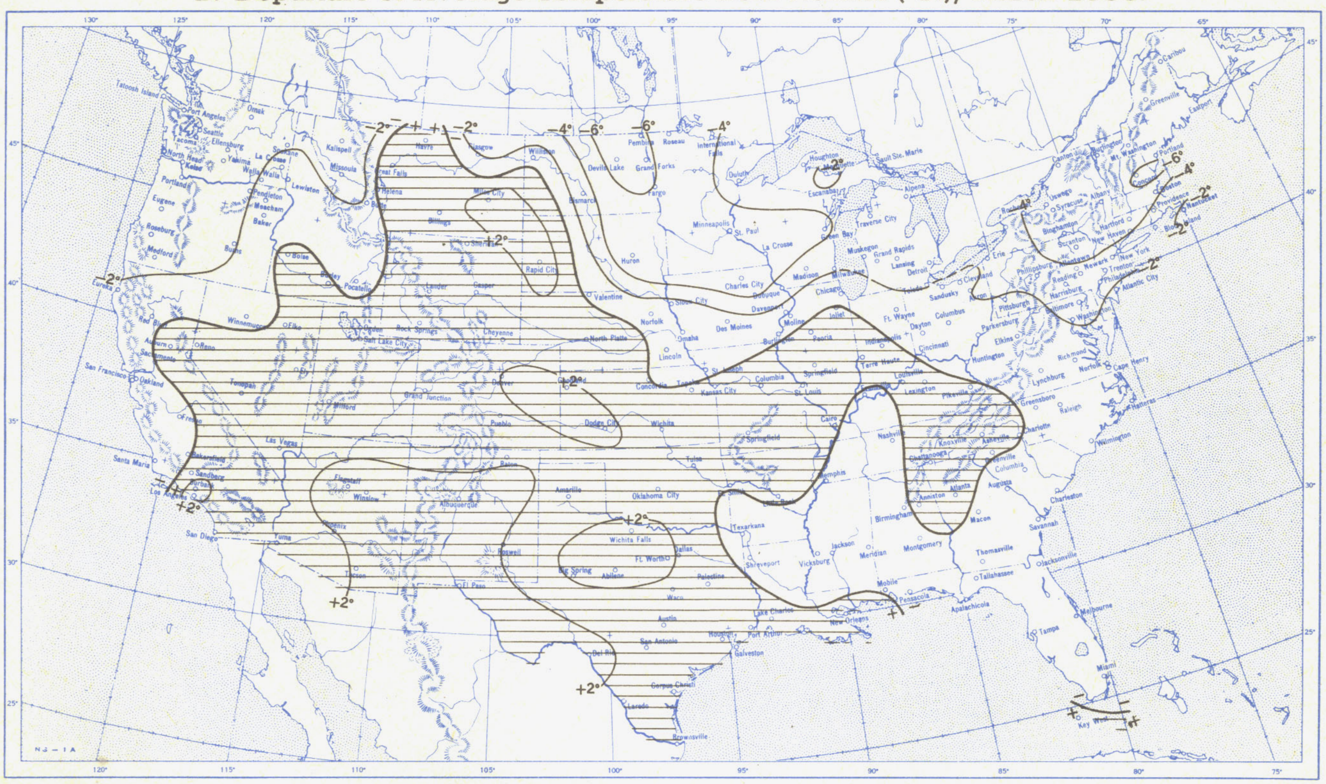
Chart I. A. Average Temperature (°F.) at Surface, March 1956.



B. Departure of Average Temperature from Normal (°F.), March 1956.

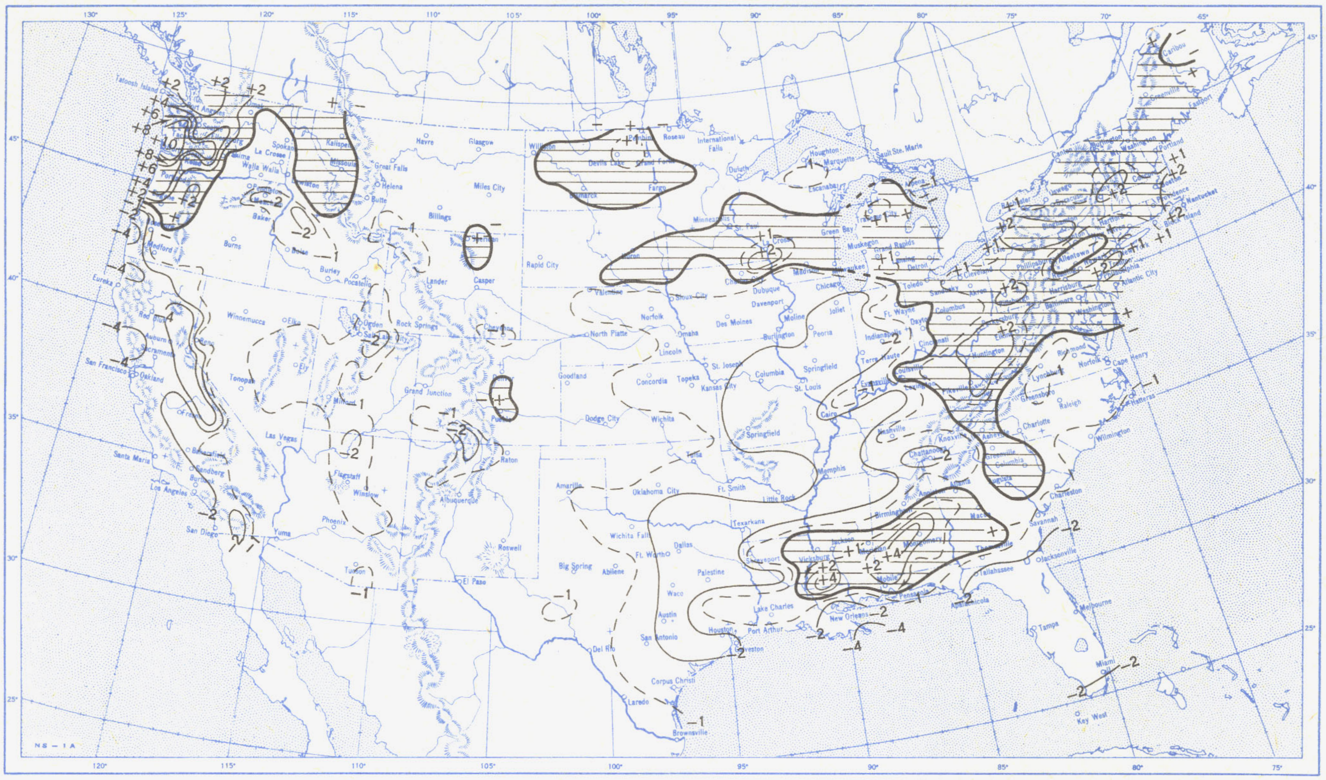


A. Based on reports from 800 Weather Bureau and cooperative stations. The monthly average is half the sum of the monthly average maximum and monthly average minimum, which are the average of the daily maxima and daily minima, respectively.
B. Normal average monthly temperatures are computed for Weather Bureau stations having at least 10 years of record.

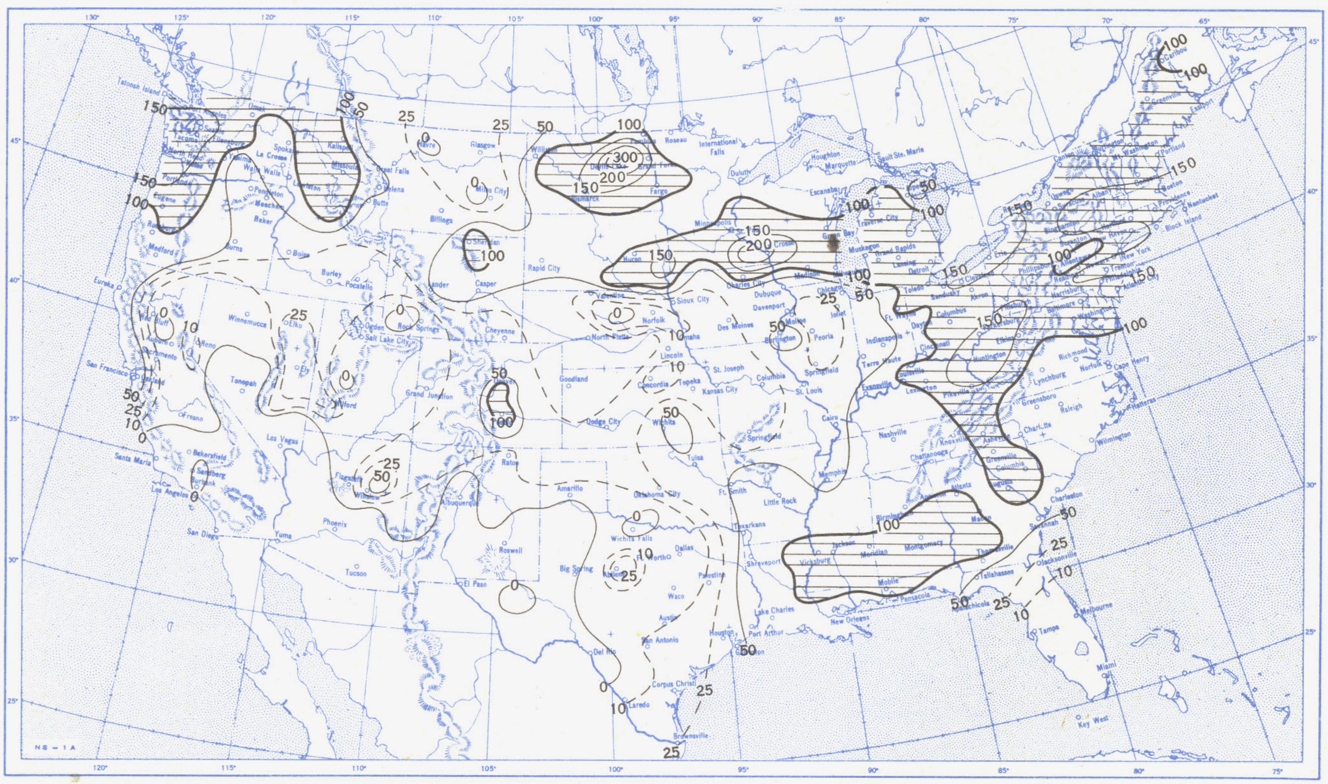
Chart II. Total Precipitation (Inches), March 1956.

Based on daily precipitation records at 800 Weather Bureau and cooperative stations.

Chart III. A. Departure of Precipitation from Normal (Inches), March 1956.

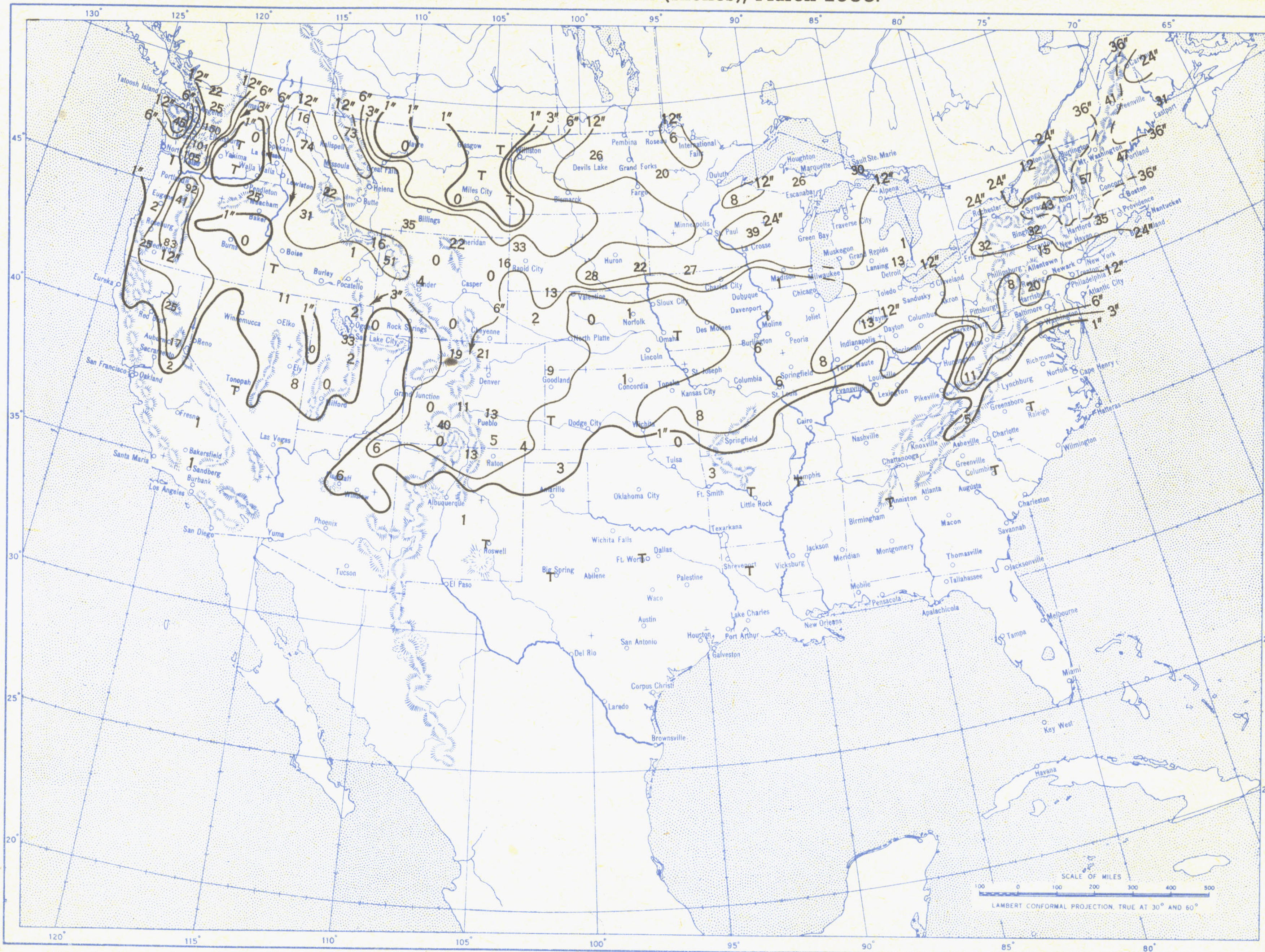


B. Percentage of Normal Precipitation, March 1956.



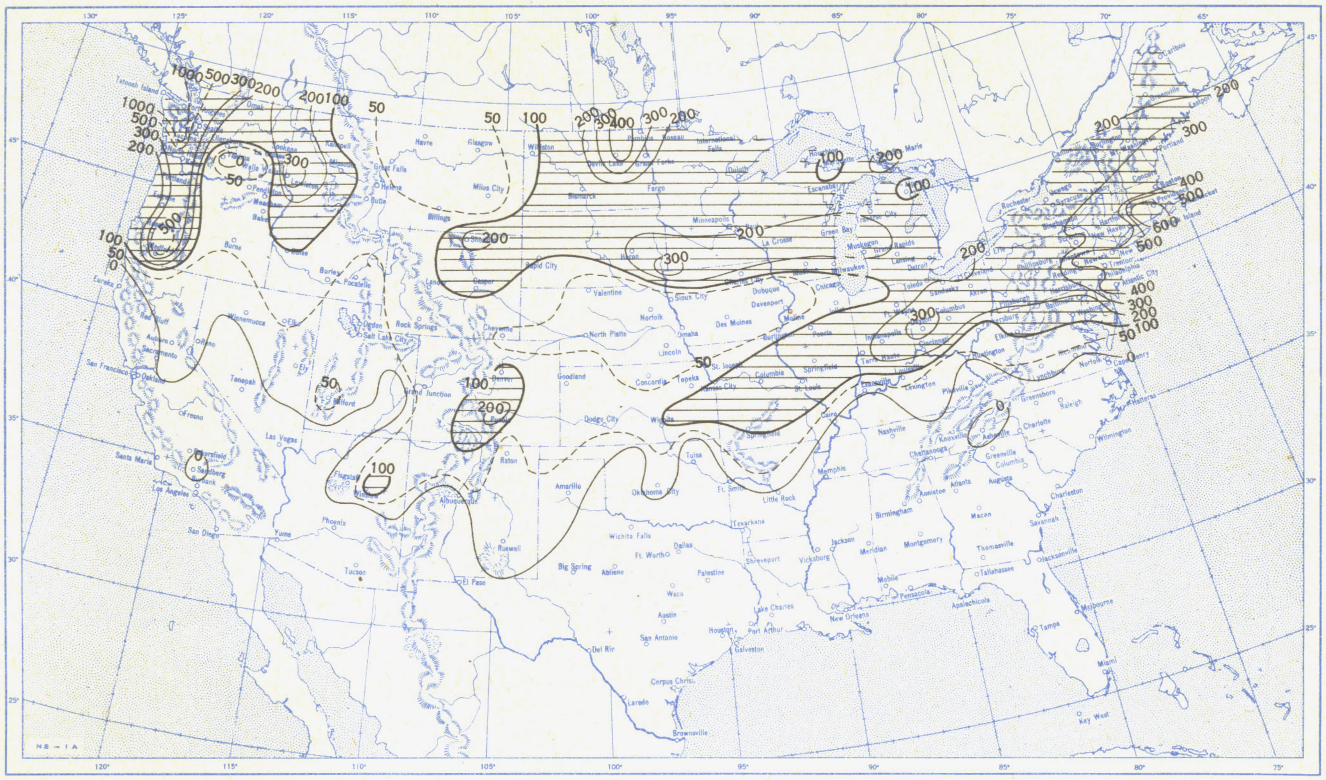
Normal monthly precipitation amounts are computed for stations having at least 10 years of record.

Chart IV. Total Snowfall (Inches), March 1956.

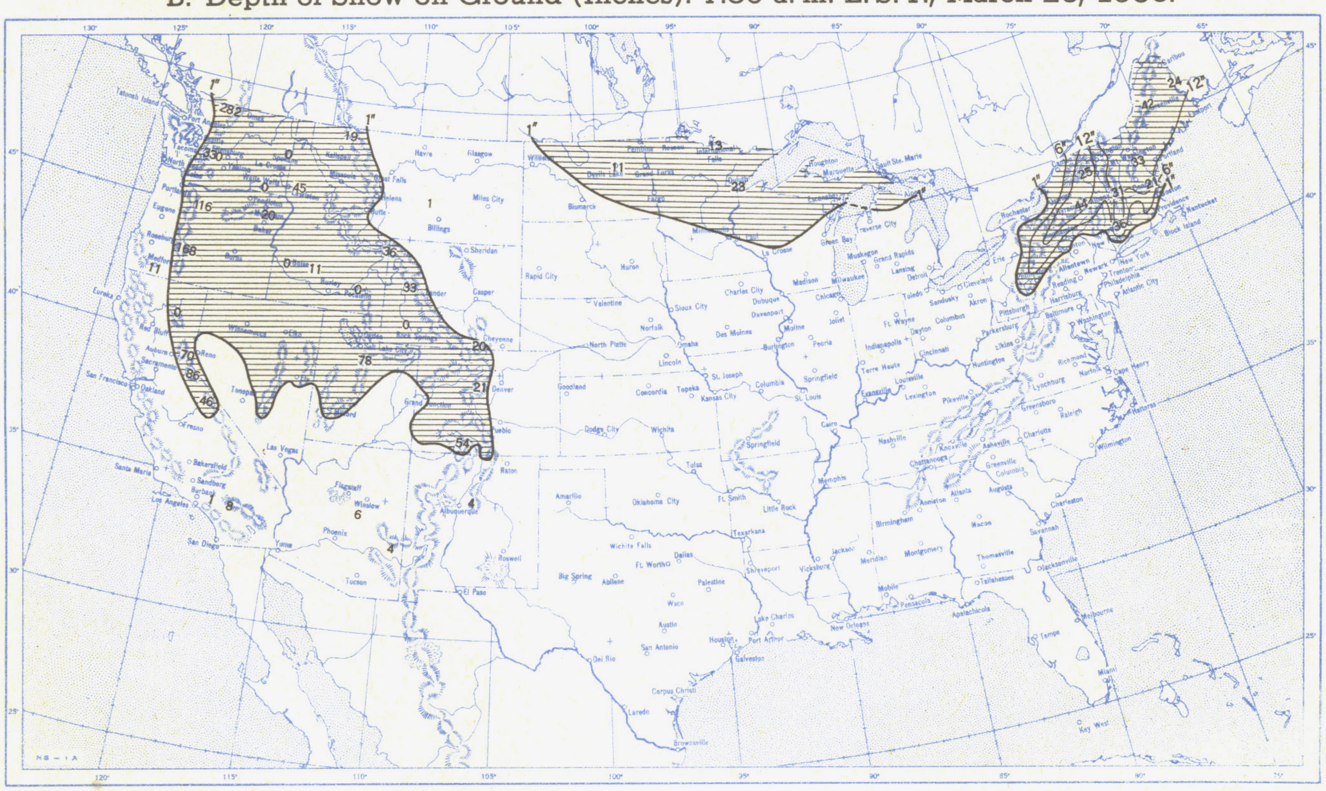


This is the total of unmelted snowfall recorded during the month at Weather Bureau and cooperative stations. This chart and Chart V are published only for the months of November through April although of course there is some snow at higher elevations, particularly in the far West, earlier and later in the year.

Chart V. A. Percentage of Normal Snowfall, March 1956.

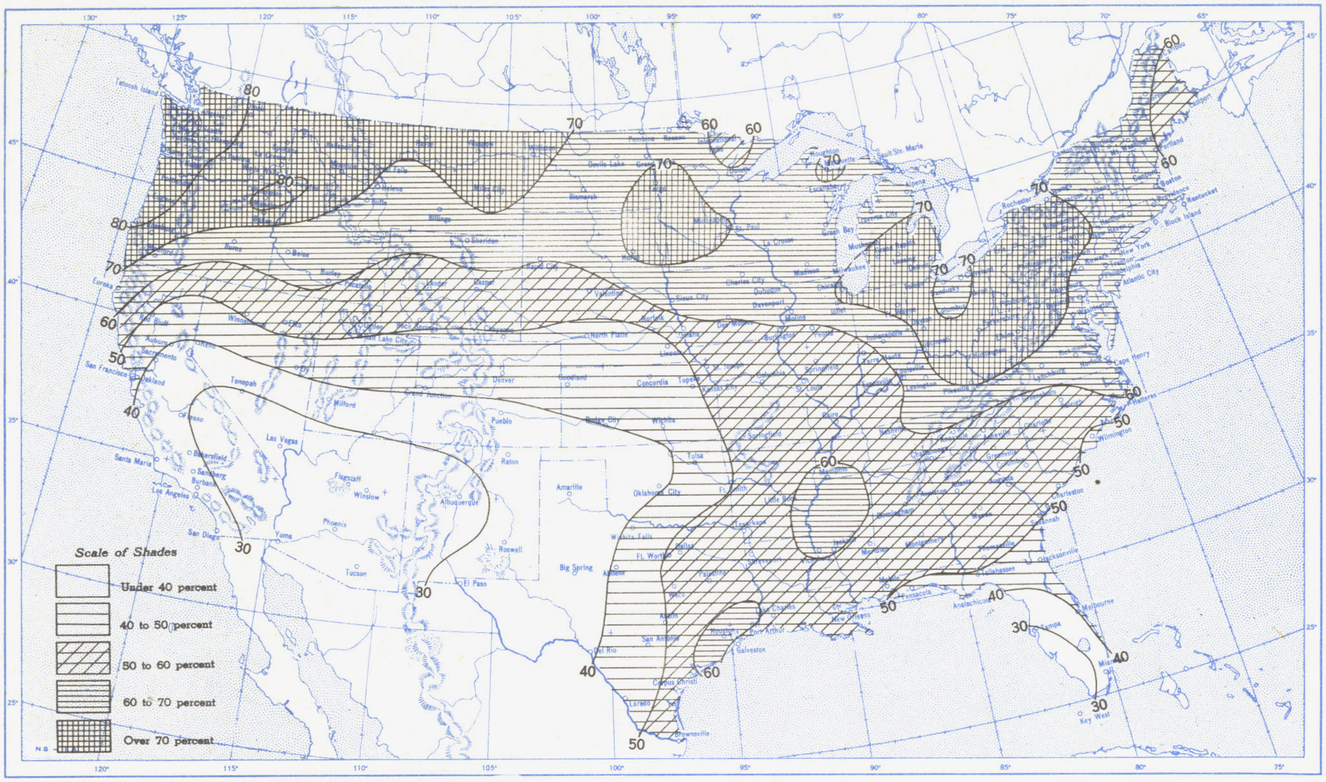


B. Depth of Snow on Ground (Inches). 7:30 a. m. E. S. T., March 26, 1956.

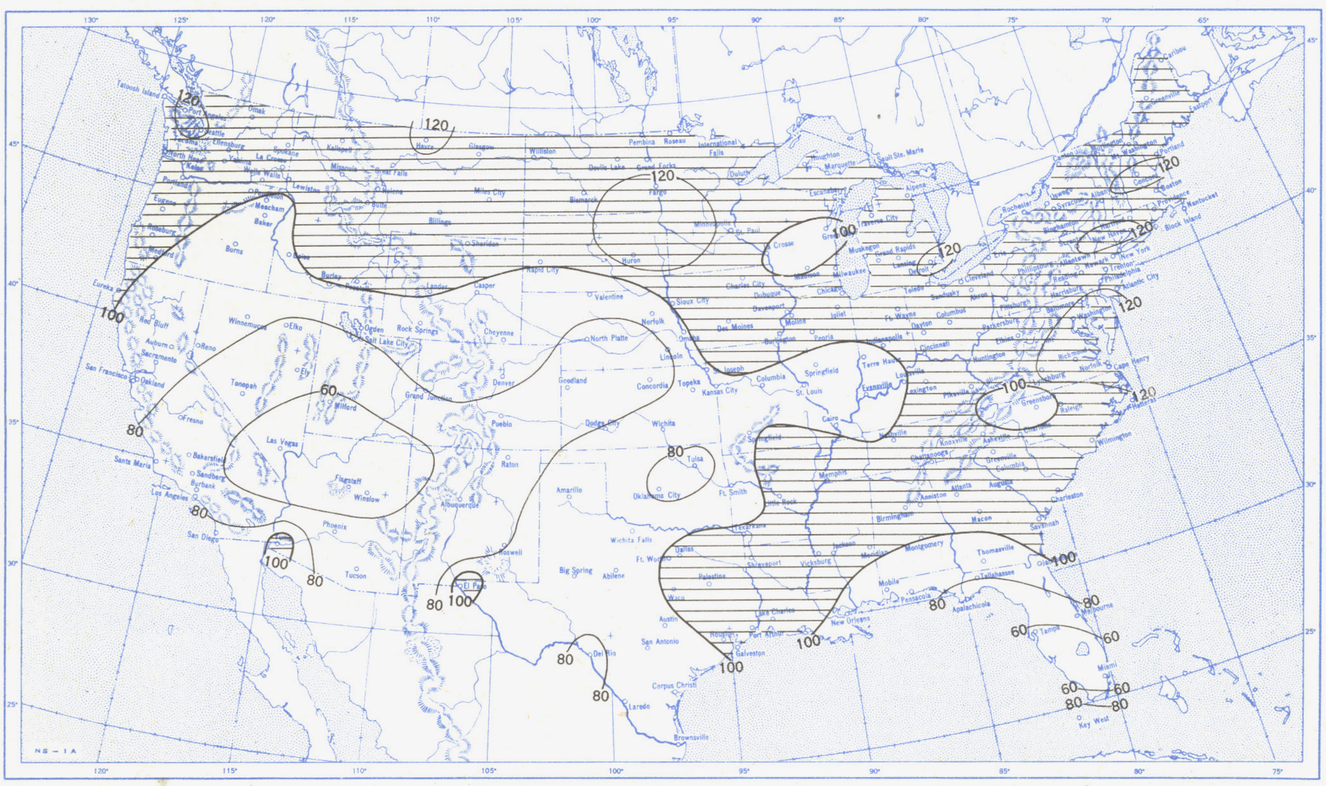


A. Amount of normal monthly snowfall is computed for Weather Bureau stations having at least 10 years of record.
B. Shows depth currently on ground at 7:30 a. m. E. S. T., of the Tuesday nearest the end of the month. It is based on reports from Weather Bureau and cooperative stations. Dashed line shows greatest southern extent of snowcover during month.

Chart VI. A. Percentage of Sky Cover Between Sunrise and Sunset, March 1956.

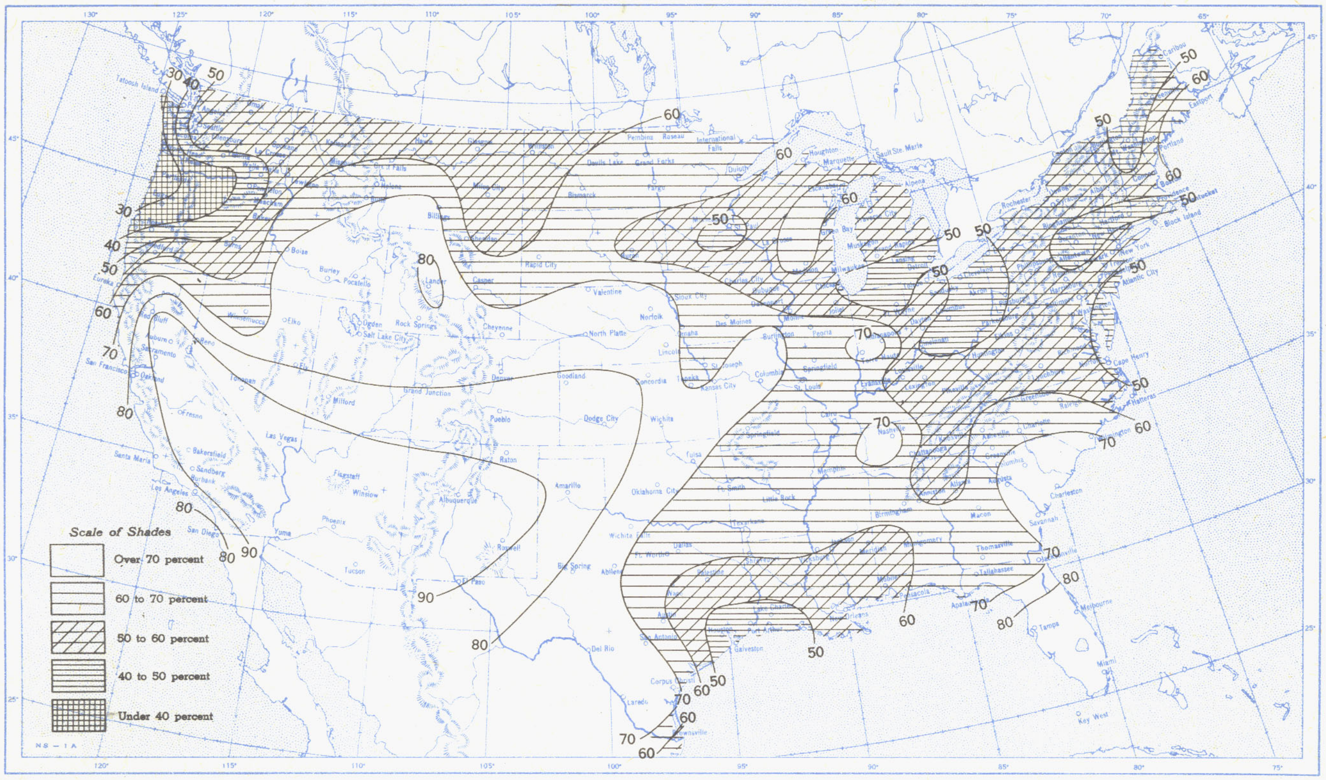


B. Percentage of Normal Sky Cover Between Sunrise and Sunset, March 1956.

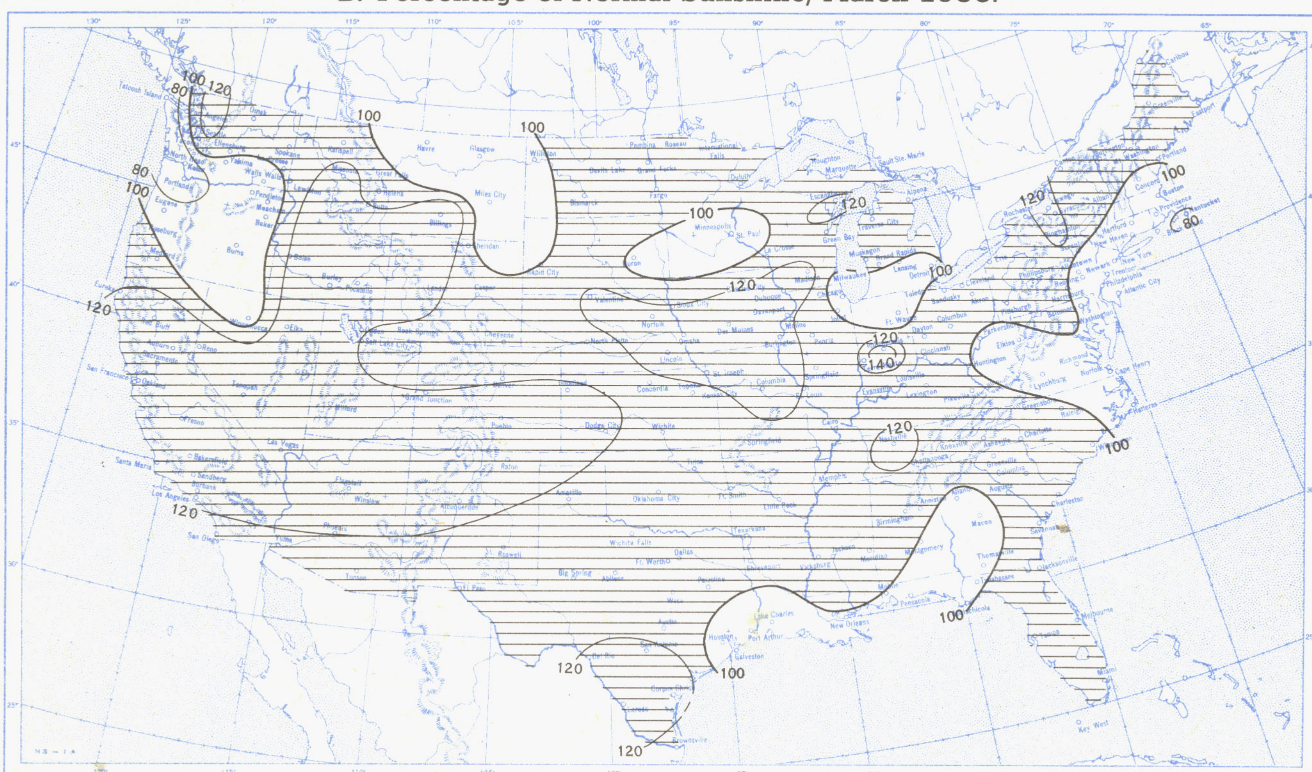


A. In addition to cloudiness, sky cover includes obscuration of the sky by fog, smoke, snow, etc. Chart based on visual observations made hourly at Weather Bureau stations and averaged over the month. B. Computations of normal amount of sky cover are made for stations having at least 10 years of record.

Chart VII. A. Percentage of Possible Sunshine, March 1956.



B. Percentage of Normal Sunshine, March 1956.



A. Computed from total number of hours of observed sunshine in relation to total number of possible hours of sunshine during month. B. Normals are computed for stations having at least 10 years of record.

Chart VIII. Average Daily Values of Solar Radiation, Direct + Diffuse, March 1956. Inset: Percentage of Mean Daily Solar Radiation, March 1956. (Mean based on period 1951-55.)

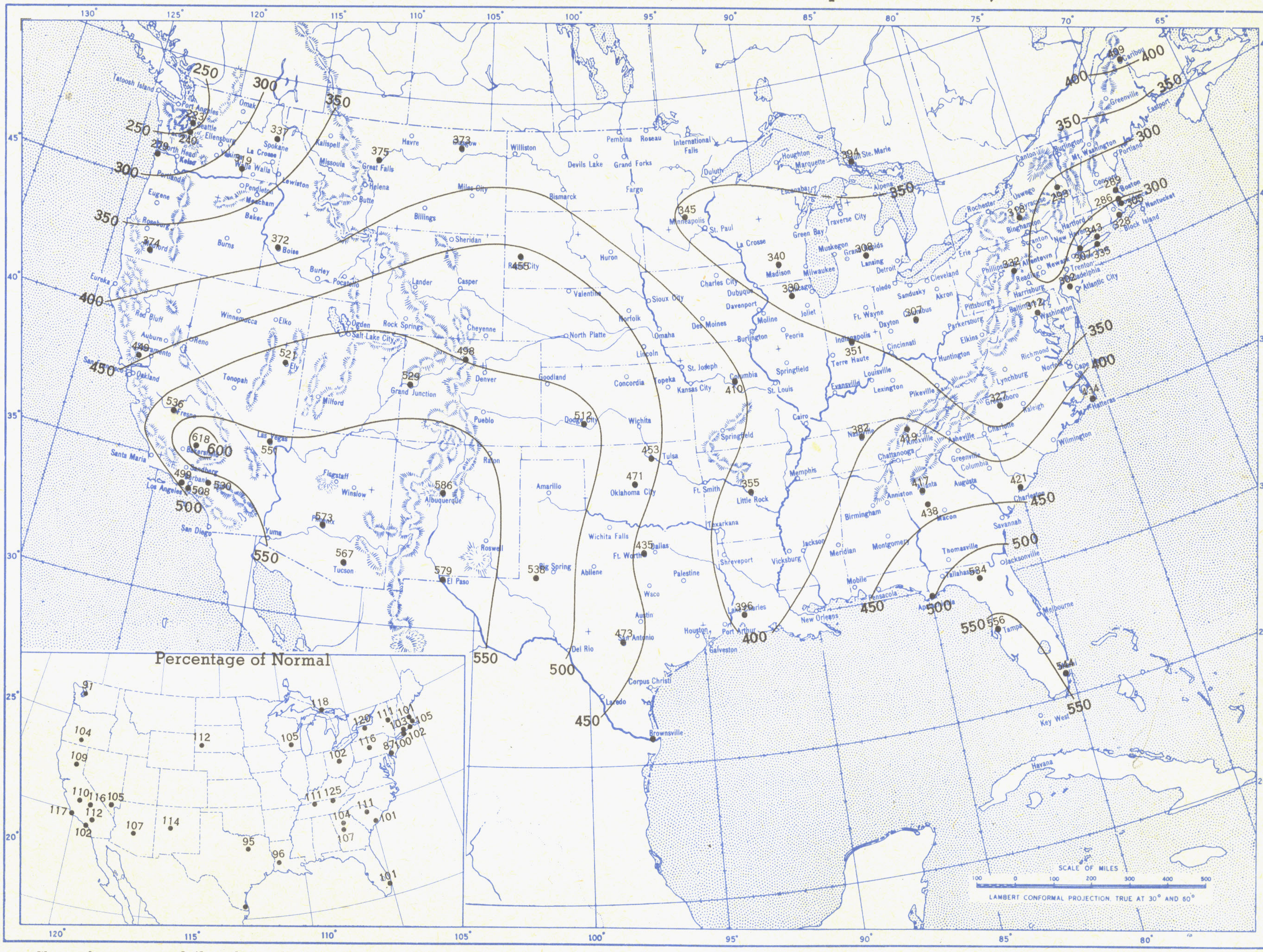
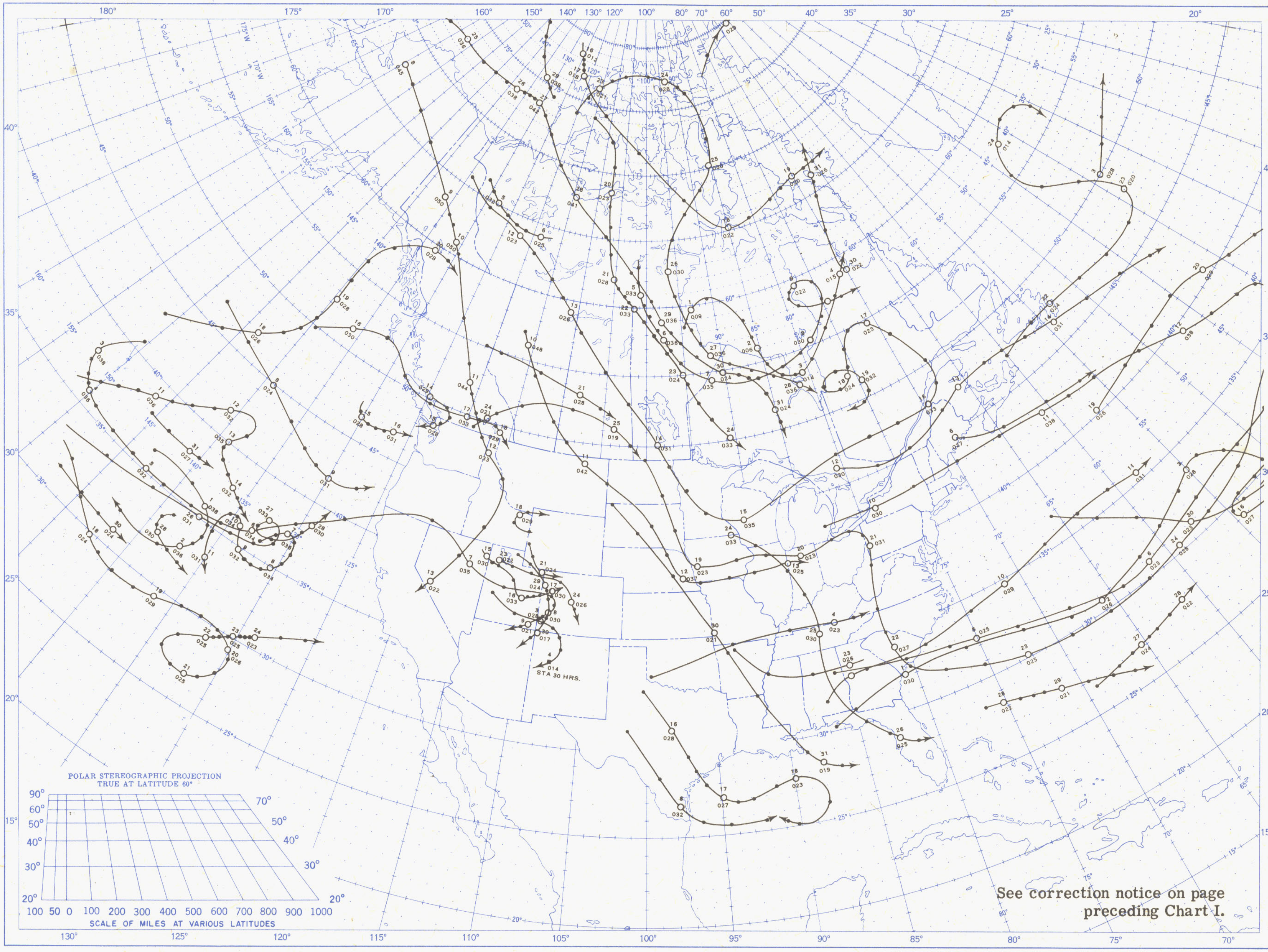


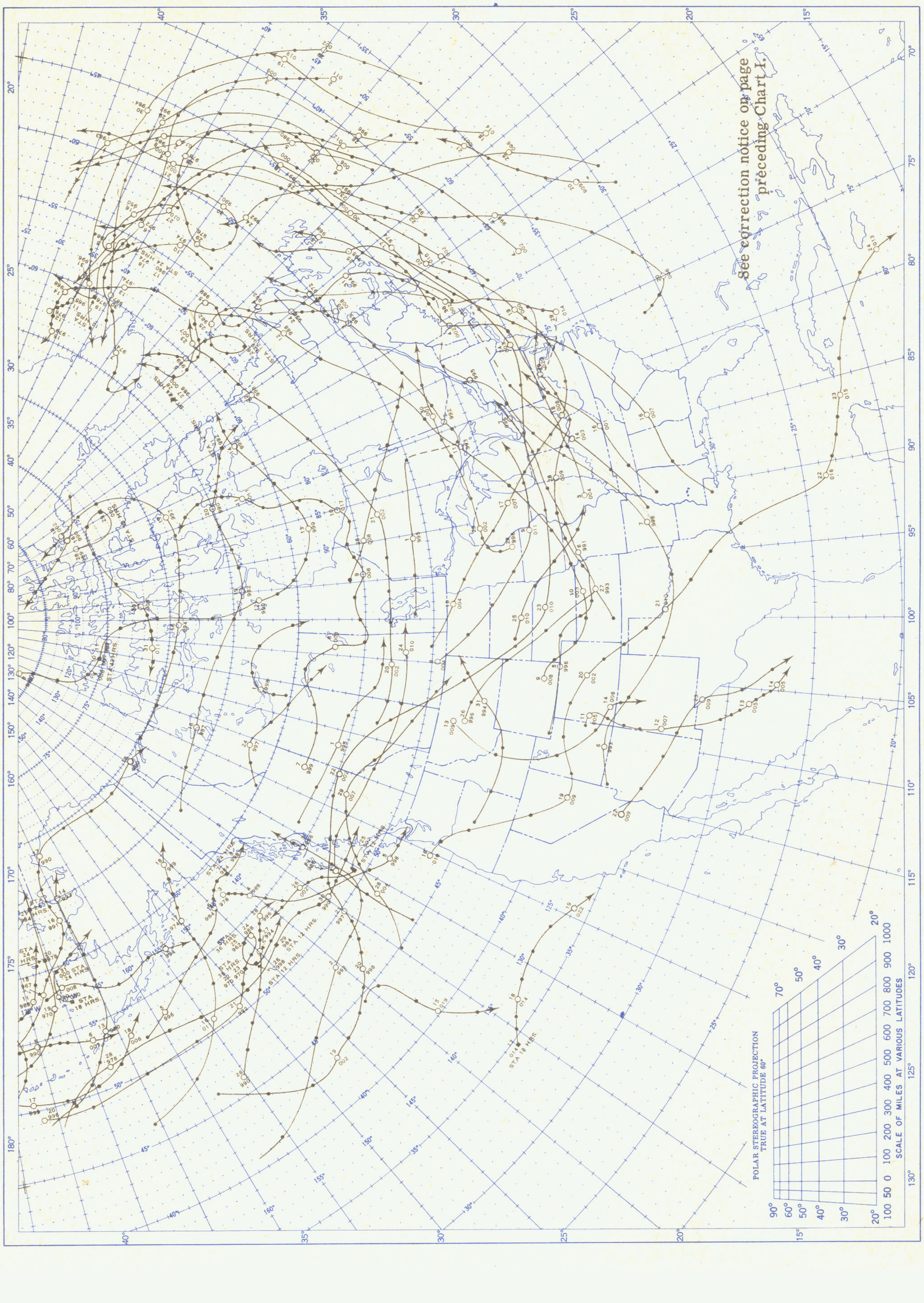
Chart shows mean daily solar radiation, direct + diffuse, received on a horizontal surface in langleys (1 langley = 1 gm. cal. cm. $^{-2}$). Basic data for isolines are shown on chart. Further estimates are obtained from supplementary data for which limits of accuracy are wider than for those data shown.

Chart IX. Tracks of Centers of Anticyclones at Sea Level, March 1956.



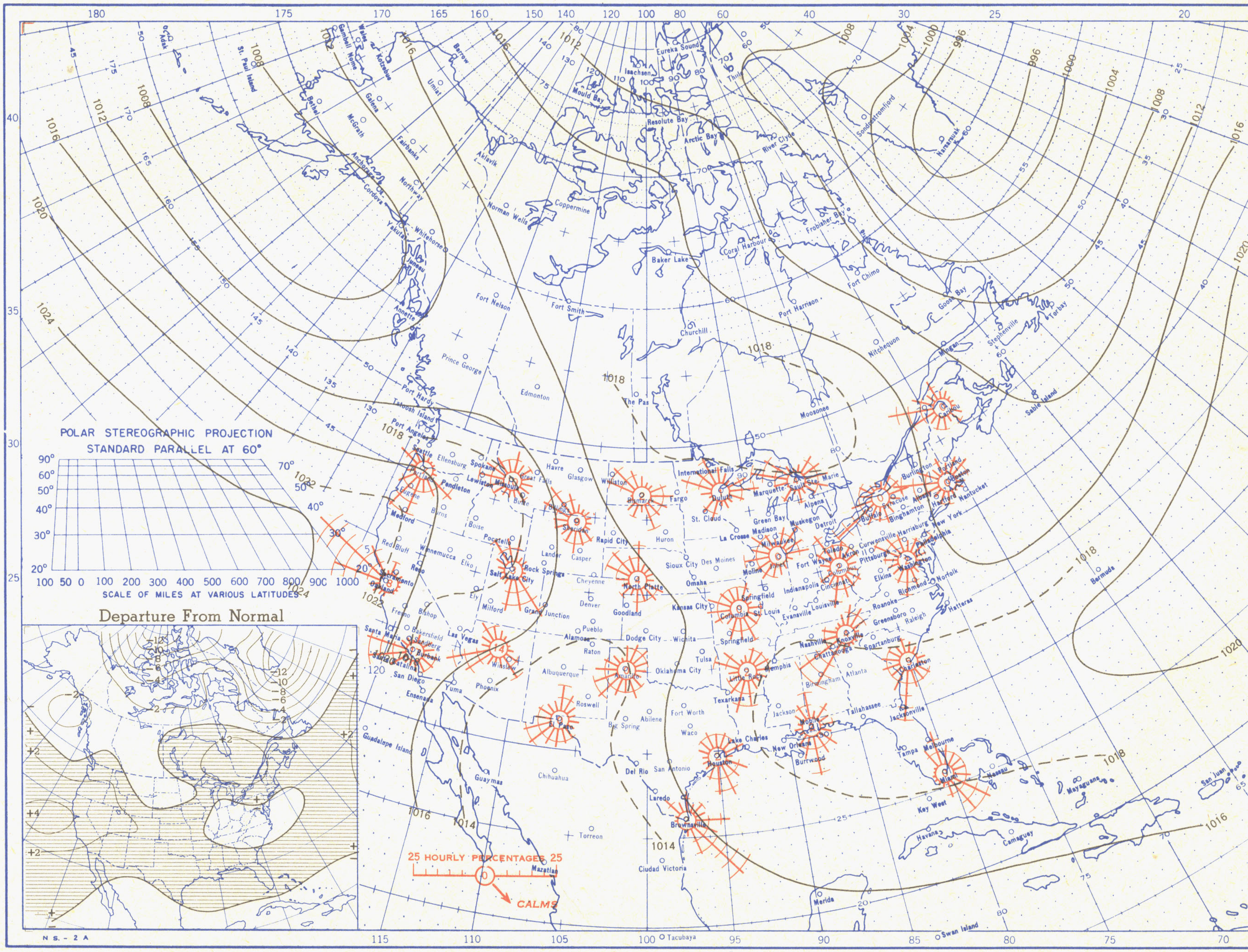
Circle indicates position of center at 7:30 a. m. E. S. T. Figure above circle indicates date, figure below, pressure to nearest millibar. Dots indicate intervening 6-hourly positions. Squares indicate position of stationary center for period shown. Dashed line in track indicates reformation at new position. Only those centers which could be identified for 24 hours or more are included.

Chart X. Tracks of Centers of Cyclones at Sea Level, March 1956.



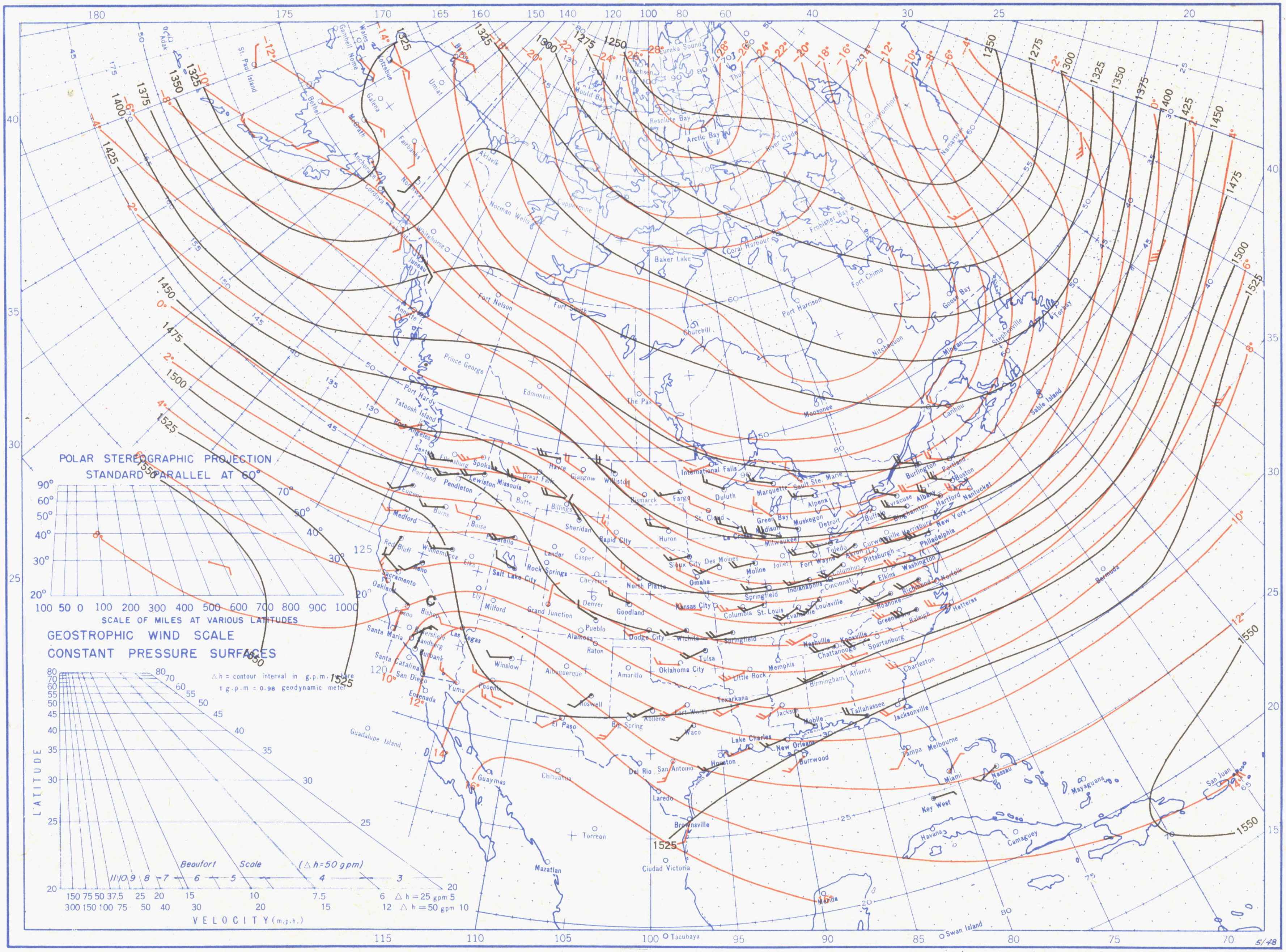
Circle indicates position of center at 7:30 a. m. E. S. T. See Chart IX for explanation of symbols.

Chart XI. Average Sea Level Pressure (mb.) and Surface Windroses, March 1956. Inset: Departure of Average Pressure (mb.) from Normal, March 1956.



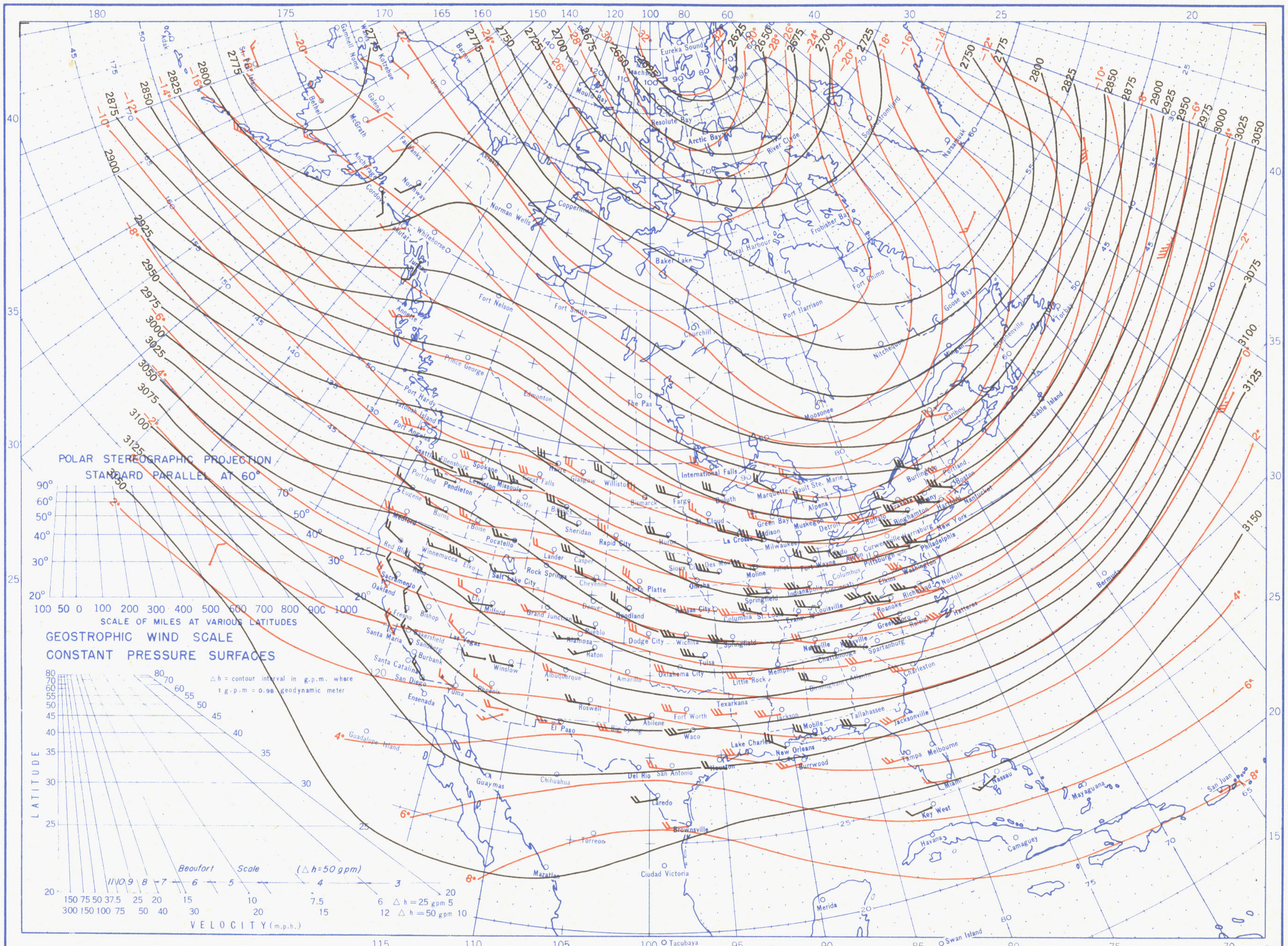
Average sea level pressures are obtained from the averages of the 7:30 a. m. and 7:30 p. m. E. S. T. readings. Windroses show percentage of time wind blew from 16 compass points or was calm during the month. Pressure normals are computed for stations having at least 10 years of record and for 10° intersections in a diamond grid based on readings from the Historical Weather Maps (1899-1939) for the 20 years of most complete data coverage prior to 1940.

Chart XII. Average Dynamic Height in Geopotential Meters (1 g.p.m. = 0.98 dynamic meters) of the 850-mb. Pressure Surface, Average Temperature in °C. at 850 mb., and Resultant Winds at 1500 Meters (m.s.l.), March 1956.



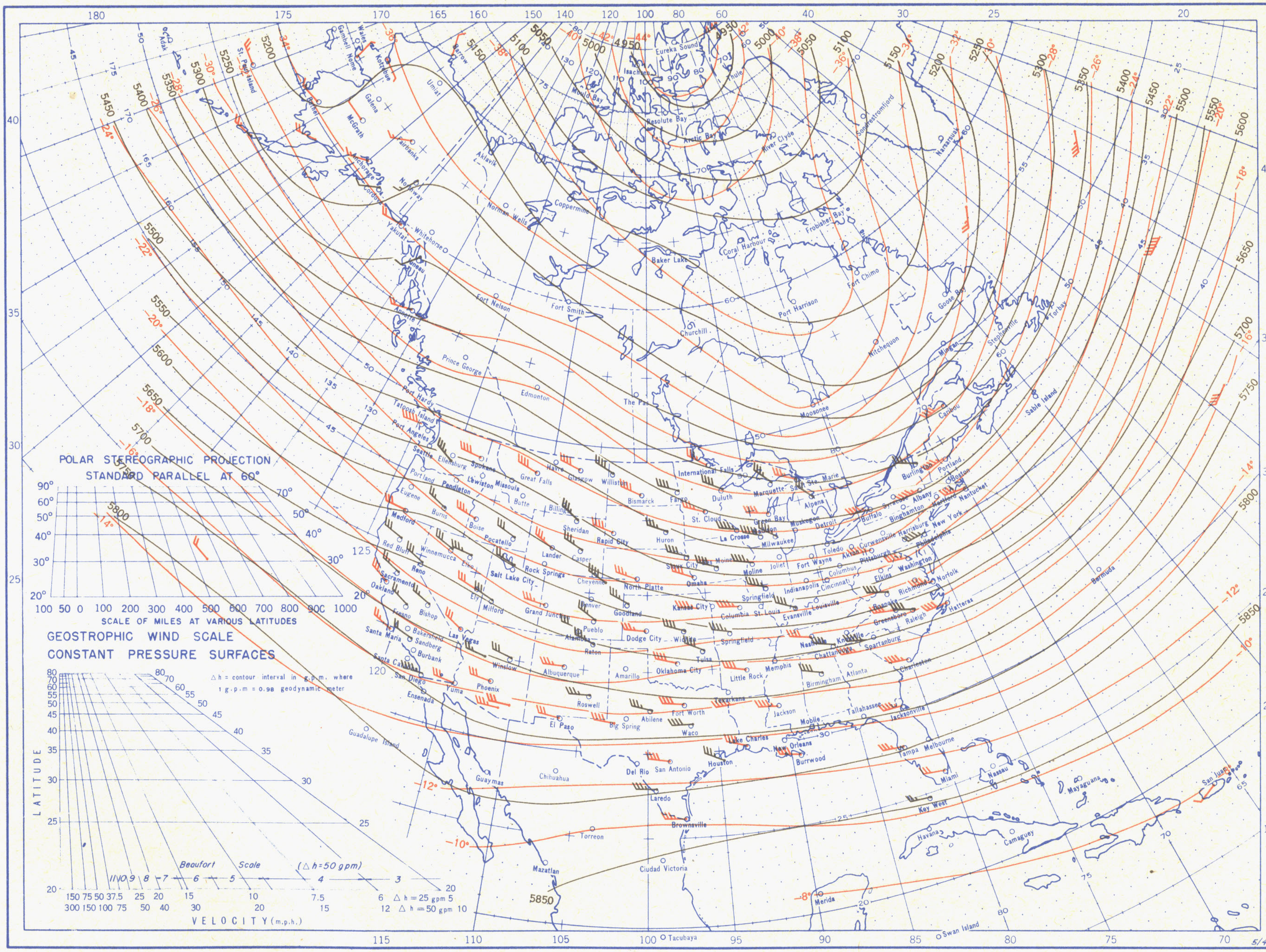
Contour lines and isotherms based on radiosonde observations at 0300 G. M. T. Winds shown in black are based on pilot balloon observations at 2100 G. M. T.; those shown in red are based on rawins taken at 0300 G. M. T. Wind barbs indicate wind speed on the Beaufort scale.

Chart XIII. Average Dynamic Height in Geopotential Meters (1 g.p.m.. = 0.98 dynamic meters) of the 700-mb. Pressure Surface, Average Temperature in °C. at 700 mb., and Resultant Winds at 3000 Meters (m.s.l.), March 1956.



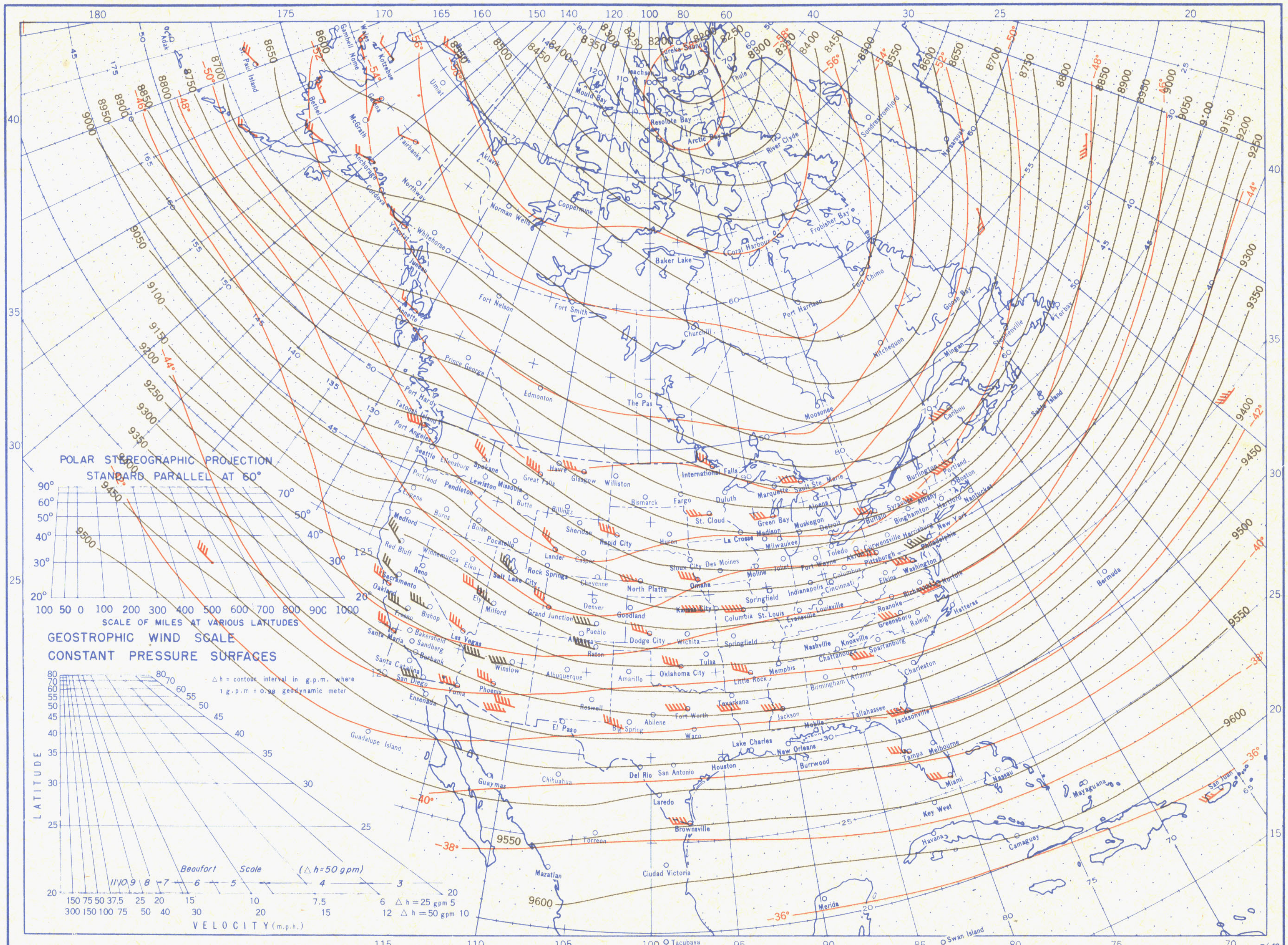
Contour lines and isotherms based on radiosonde observations at 0300 G. M. T. Winds shown in black are based on pilot balloon observations at 2100 G. M. T.; those shown in red are based on rawins taken at 0300 G. M. T. Wind barbs indicate wind speed on the Beaufort scale.

Chart XIV. Average Dynamic Height in Geopotential Meters (1 g.p.m. = 0.98 dynamic meters) of the 500-mb. Pressure Surface, Average Temperature in °C. at 500 mb., and Resultant Winds at 5000 Meters (m.s.l.), March 1956.



Contour lines and isotherms based on radiosonde observations at 0300 G. M. T. Winds shown in black are based on pilot balloon observations at 2100 G. M. T.; those shown in red are based on rawins at 0300 G. M. T. Wind barbs indicate wind speed on the Beaufort scale.

Chart XV. Average Dynamic Height in Geopotential Meters (1 g.p.m. = 0.98 dynamic meters) of the 300-mb. Pressure Surface, Average Temperature in °C. at 300 mb., and Resultant Winds at 10,000 Meters (m.s.l.), March 1956.



Contour lines and isotherms based on radiosonde observations at 0300 G. M. T. Winds shown in black are based on pilot balloon observations at 2100 G. M. T.; those shown in red are based on rawins at 0300 G. M. T. Wind barbs indicate wind speed on the Beaufort scale.